A RISK-CONSTRAINED ANALYSIS OF ALTERNATIVE BEEF-FORAGE SYSTEMS IN EASTERN OKLAHOMA

By

RICHARD BLAINE RAWLINS

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Thesis Approved:

Daniel J. Bernardo
Thesis Adviser

Francis M. Epplin

Odell L. Walker

Norman N. Durham
Dean of the Graduate College

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CHAPTER I

INTRODUCTION

Beef-Cattle Production in Oklahoma

The large number of cattle in Oklahoma make an important contribution to the state's economy. The development of Oklahoma has been tied to the cattle industry for many years. The trail drives of the Texas trail herds led ranchers to realize the value of the forage resources that are available throughout the state. As the state became more settled, heavier and more intensive use of the different forages occurred. In 1891, the first year of cattle inventory reports, there were 787,000 head of cattle in Oklahoma. The January 1, 1986, report stated that there were 5.2 million head of cattle in Oklahoma. This is approximately the level at which the number of cattle has remained since 1971 (Jobes).

In 1986, cattle generated 1.15 billion dollars of revenue within the state of Oklahoma. Beef cattle ranked first in value of production among agricultural commodities, followed by wheat which generated 347 million dollars. Cattle generated over 78 percent of the cash receipts from livestock sales and 54 percent from all agricultural commodities. Also, in 1986 the state was ranked fourth among all states in terms of total number of cows and calves (Oklahoma Agricultural Statistics).

The distribution of cattle enterprises within the state has shifted in recent years. Farmers in western Oklahoma have moved toward more flexible stocker enterprises and away from cow-calf operations. Over the past decade, most counties in western Oklahoma have decreased in county rank while eastern counties have increased in rank. Seven of the top ten counties in terms of total cattle production are located in western Oklahoma, while eight of the top ten counties in terms of total beef-cows are located in the eastern half of the state (Oklahoma Agricultural Statistics).

Approximately 47 percent of Oklahoma's total land area, or 20.64 million acres, were grazed to some extent in 1982. Another 1.7 million acres were used for the production of hay or forage products. Of the 71,000 farms in the state, 65,000 had one or more head of beef-cattle. This is compared to less than 6,000 farms having hog, dairy or sheep enterprises (Oklahoma Agricultural Statistics). Obviously, a successful beef production sector is requisite to the maintenance of a strong agricultural economy in Oklahoma.

In order to stay competitive with other meat sources, new methods with the potential to lower the cost of producing beef must be introduced. From 1955 to 1975, the average cost of producing a pound of poultry increased 50 percent while the beef production costs increased 275 percent (Trapp). Farmers and ranchers need better information and knowledge of production alternatives and accurate estimates of the income expected from these alternatives in order to remain competitive. At the same time, it is important to also consider the income variability associated with these options.

The economic environment faced by beef producers is frequently harsh. As with most phases of agriculture, very astute management is required in order to make the proper decisions to maintain firm profitability, and in several cases, survivability. Declining beef consumption, low enterprise returns, decreasing land values, and high debt burdens are economic realities that each producer, and the industry as a whole, is faced with. Long traditions in family farming and initial strong financial positions offer no assurance of continued existence in the business. Doing things the way they have "always been done" or continuing to operate without explicit long-term goals or financial direction is forcing a great number of today's farmers and ranchers out of business. The hard economic realities of today are requiring farmers and ranchers to make sound production, marketing, and financial decisions if they desire to remain in the business for an extended period.

Problem Definition

The central problem that this study will address is that of decision making under uncertainty. Risk and uncertainty cause a reduction in the reliability of future plans of producers and serve to shorten planning horizons. The principle need for management arises from the uncertainty associated with expectations used by producers in decision making (Hopkin et al.). Uncertainty exists in the mind of the manager when expectations are within a range of possible outcomes as opposed to a certain yield or price outcome.

Like most agricultural producers, cattlemen operate in an uncertain economic environment. Income instability results from production, marketing and financial uncertainty. The beef-forage producer is exposed to a wider scope of uncertainty than the typical crop producer. A primary source of this uncertainty is derived from variability in both the amount and timing of rainfall and other critical climatic variables, and the associated uncertainty in the quantity and quality of forage produced. In addition to this risk shared by virtually all farmers, the livestock producer faces the added production risk of converting forage produced into pounds of beef. Associated with this conversion are uncertainties concerning genetics, disease, response to feed additives and several other variable inputs.

In addition to production risks, a beef producer faces market or price risk. Pricing in the beef cattle system is complex; for example, the feedlot industry's demand for calves depends heavily on grain and beef price relationships. Generally, when the cost of variable inputs (e.g., feed grain) is high relative to beef prices, feedlot operators prefer heavier calves which have been kept on grass for a longer period of time. In contrast, when feed grain costs are low, feeders demand lighter calves. As a result of the feedlot industry's fluctuating demand, the ranch manager has the difficult problem of allocating forage resources among alternative livestock enterprises.

Due to the climate of the study area and the potential to grow different forages throughout the year, eastern Oklahoma producers have several livestock marketing options available. Cow-calf producers can retain ownership until slaughter or chose to market their cattle any time between weaning and slaughter. There are several tools available to producers to minimize the uncertainty associated with marketing decisions. Forward contracting, hedging, buying option puts, as well as other innovative marketing alternatives are available. Each of these alternatives are potential methods of risk reduction and have varying degrees of effectiveness when used during alternative stages of beef production.

An additional source of price risk faced by cattle producers results from input price variability. Inputs that are essential to the operation of a ranch such as equipment, fuel, and labor must be purchased regardless of the price. C.E. Shafer, in a publication addressing the seasonality of prices received by Texas agricultural producers, concluded that while net farm income from farming (livestock producers were included) increased and decreased during the 1955 to 1975 period, production costs increased each of the twenty years.

A third source of risk that farmers must face is financial risk. This source of risk has increased dramatically in the past decade due to fiscal and monetary decisions by the government as well as other exogenous influences. Included among the factors that explain the added variability are: a) modified government programs for many U.S. commodities, b) rapid changes in crop inventories, c) devaluation of the U.S. dollar, d) variation in world production, and e) expanded and unpredictable fluctuations in foreign demand (Barry).

The numerous sources of uncertainty, and alternative methods of dealing with it, complicate the decision process and sometimes lead to what appears to be random behavior. Greater managerial effort is often given to managing risk than to earning greater returns (Hopkin et al.).

A risk averting producer will value a risky alternative at less than its expected value. That difference may be conceived as a cost of risk bearing required to make the risky expectation equivalent to one that is certain. The greater the aversion to risk, the higher will be the risk cost (Barry).

There are several alternatives from which a cattle producer may select to deal with risk. His problem may be seen as selecting the best combination of inputs (e.g., forage, supplements, etc.) which applied to his livestock operation can assure him a maximum profit for a given level of risk. Previous research reporting trade-offs between net income and stability of income have indicated that ranch managers are not simply profit maximizers, but are also concerned with risk minimization (Whitson).

In summary, a rancher must be concerned with several different aspects of the forage-livestock production system, their balance and interrelationships. The various components that make up the production system are livestock enterprises, forage and grain activities, and production practices used to grow and market the product. New and different production technologies must be evaluated as to their effect on the entire system and not just one isolated component. Analysis of individual components of the production system can result in overlooking important interactions between production segments, and thus result in inefficient decisions.

A better understanding of the profitability and risk associated with alternative farm enterprises will assist producers in making decisions such as how many animals to produce, what kind to grow, and when to have them ready for market. It may also help producers as a group adjust total production more closely to meet future demands.

Objectives of the Study

The general objective of this study is to develop and apply a static model, which incorporates risk from variability in forage yields and cattle prices as a decision constraint, and use the model to identify efficient livestock-forage production systems for commercial cattle producers in eastern Oklahoma.

Specific objectives are:

1. To analyze selected forage management decisions faced by eastern Oklahoma cattle producers.
2. To determine the economic feasibility of alternative cow-calf and stocker enterprises available to eastern Oklahoma livestock producers.
3. To analyze the interactions of crop and livestock enterprises on eastern Oklahoma farms and ranches, and identify efficient production systems under alternative settings and economic situations.

4. To estimate the impact of alternative production systems identified in (3) on farm income variability and determine the effect of the producer's willingness to bear risk on efficient production organization.

Procedures

This study will utilize a MOTAD mathematical programming model to determine the risk efficient allocation of resources for a beef-forage producer in eastern Oklahoma. MOTAD is a linear programming formulation that can be used to derive efficient farm organizations that provide the minimum return given constraints on the level of risk experienced by the decision maker. Application of the model results in the development of an expected income (E) - total negative deviation (A) frontier. The E-A frontier is a useful tool to evaluate the risk-return tradeoffs facing the agricultural producer.

The first step taken in developing the programming model will require the collection of the technical relationships of plant and animal response to alternative management strategies. This information will then be combined with price and cost information to estimate expected returns and costs for alternative forage activities. Similar data, reporting the resource requirements of alternative cattle enterprises and the relationship between resource use and beef production, will be combined with cost and return information to determine expected income generated by alternative livestock activities.

Individual forage and livestock schemes will be combined into alternative production systems to represent the expected production, cost, and resource requirements of the proposed production system. NRC data, as well as other timely nutritional publications, will be utilized in the development of physical relationships to represent the interaction between forage quality and quantity and the subsequent pounds of beef produced. This information will be coupled with historical price, cost, and yield variability data in the MOTAD model to incorporate the effect of risk upon the optimum whole-ranch production plan. The MOTAD model will then be used to analyze the effect of alternative production practices upon risk-return relationships. From this analysis, a set of risk-efficient whole-ranch plans for eastern Oklahoma beef-forage producers characterized by alternative risk preferences will be generated.

Description of the Study Area

As defined for this study, eastern Oklahoma covers approximately 13.6 million acres spread over 25 counties (Figure 1). The eastern portion of the state contributes significantly to the state's agricultural industry and, in particular, to the cow-calf sector. The total cattle and calves inventory for the region on January 1, 1982, was 4,673,900 head, 32 percent of the state total. At the same point in time, the number of beef cows in this region was 1,830,253 or 37 percent of the total (Census of Agriculture). Cash receipts from cattle and calves sold for 1982 in the Eastern region was 300 million dollars, approximately 22 percent of the state's total (Census of Agriculture). The study area is also a major hay production region, accounting for 36 percent of the state's annual hay production.

In eastern Oklahoma, annual rainfall increases in moving from north, south. Average precipitation ranges from 39.38 inches in the northeastern portion of the state to 47.80 inches in the southern area (Oklahoma Agricultural Statistics). On a monthly basis, the trend is consistent from north to south with the exceptions of June and September. In June and September the pattern is

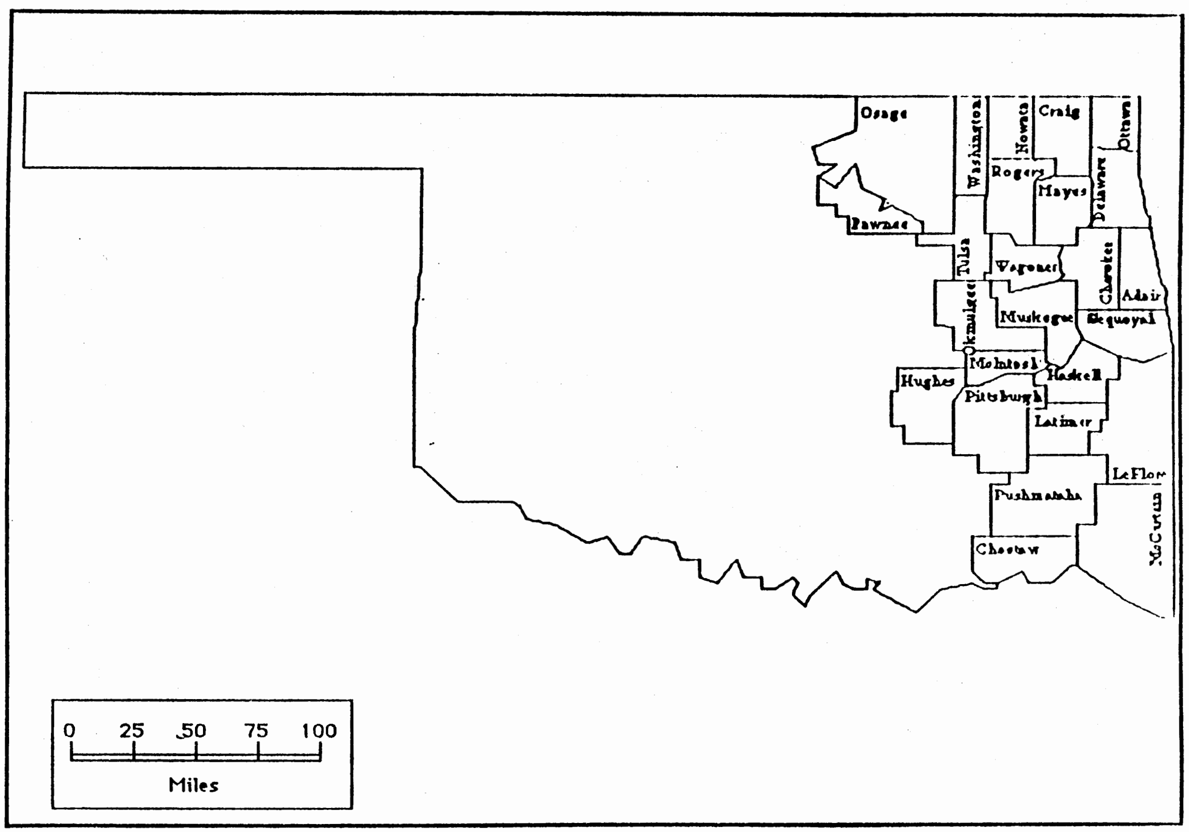

Figure 1. Study Area

reversed and the southern portion of the study area typically receives less precipitation (Oklahoma Agricultural Statistics). Also, irregular distribution of rainfall can occur, leading to drought conditions during the summer months. The average length of growing season ranges from 240 days in the extreme south to 190 days in the northeastern corner. Killing frosts are uncommon in the southern section later than the first week in April and April 20 in the north. Killing frosts in the fall will vary from the last week in October in the north to the second week in November in the south.

The topography of the study area is very differentiated from north to south. The southern and most eastern parts of the study area are parts of the Ouachita Highlands and Ozark Highlands, respectively. These two areas make up the most rough and mountainous parts of the study area and have elevations ranging from 400 to 2600 feet. The remainder of the study area is in the Cherokee or Arkansas River Bottomlands, with elevations ranging from 300 to 700 feet.

Eastern Oklahoma has diverse soil types ranging from flood plains and bottomlands on benches next to streams and rivers to slopes greater than 30 percent. The depth of the soil varies from very deep on the bottomland to very shallow, with occasional exposure of parent material in the mountainous areas. The land in the study area has been placed into three general classifications (Gray and Galloway). The Cherokee Prairie soils developed over sedimentary shales, sandstones, and clays. Tall grasses are the natural vegetation of the Cherokee Prairies. The Ozark Highlands are generally formed on a base of cherty limestones and dolemites and generally support an Oak-Hickory type forest. The third category is the Ouachita Highlands which have formed from shales and sandstones. This very mountainous area contains little tillable or open pasture land.

Forage production in the study area is primarily limited by soil fertility and texture. The production per acre of native range is fairly standard and consistent over a wide area, yielding approximately 2000 pounds of dry forage, 50 pounds of live weight gain from yearlings or 40 pounds from weaner calves (Harlan). This can be compared with 150 to 200 pounds of production on yearlings from bermuda grass and or small grains. As a rule, a good tame pasture program will produce three to five times as much beef per acre as native range (Harlan).

Eastern Oklahoma's tame pastures are dominated by tall fescue and bermuda due to their extreme hardiness under the existing soil and climate conditions and the relatively high forage yields produced. Fescue is a cool season grass with the greatest portion of its growth occurring during the spring and early summer. A second production period is possible during the fall and mild winter days. Bermuda grass is a popular warm-season grass in eastern Oklahoma and has its highest growth rates during the late spring and summer. Small grains, wheat and to a lesser extent rye, are popular forage sources due to their high nutritional levels. Their production is limited in many areas by soil depth and steep topography. Small grains are generally productive as a forage source from the middle of October through early May.

Production of tame pastures in the study region requires high levels of both management and nutrient inputs. It is not possible to obtain high yields from tame pastures in this area without increasing the soil fertility substantially. Generally, improved pastures grown on the same soil as native range and without soil amendments do not yield as much forage as native grass (Harlan).

Beef producers in eastern Oklahoma typically employ more intensive production practices than producers in other parts of the state. While these practices allow greater decision latitude in organization of ranch operations, they also require more extensive analysis of alternative production systems.

Organization of the Study

Theoretical and empirical literature relevant to the development of the whole-farm mathematical programming model will be discussed in Chapter II. The chapter reviews the progression of the application of mathematical programming to farm-level decision making. The objectives of this study and its contributions to farm-level analysis are outlined.

Chapter III gives a brief outline of the theoretical basis on which the mathematical programming model employed in this study is based. An outline of the assumptions made and the mathematical derivation of the model is described. Also, an abbreviated tableau and description of the alternative production activities and constraints are discussed.

A detailed description of the animal and forage data requirements are explained in Chapter IV. Derivation of the nutritional requirements of the different livestock classes as well as the production capabilities of the alternative forages are discussed. Production activities included in the model and the associated assumptions are explained as well.

Chapter 'V reports the results obtained from application of the mathematical programming model to a representative ranch in the eastern Oklahoma study area. The risk-efficient optimal farm plan frontier is illustrated and the relationship between income and its variability are discussed. The effects of different economic conditions, resource limitations, and technical constraints on optimal ranch organizations and income-risk relationships are analyzed.

Finally, Chapter VI provides a review of the substantive results, a discussion of the major conclusions derived from the analysis, and recommendations for future research.

CHAPTER II

REVIEW OF RELEVANT LITERATURE

Operations research methods in economics serve as tools for determining optimal decisions and patterns of resource allocation. They are quantitative in the sense that they indicate, for example, the number of units of each activity to be produced if a stated goal such as profit maximization is to be attained. In a similar way, they can be applied to estimate the mix of strategies to be used in attaining certain goals under uncertainty. Because of these quantitative potentials, operations research methods have great usefulness in agricultural planning (Agrawal and Heady).

Operations research methods include a range of tools generally classified as mathematical programming (which includes linear programming, non-linear programming, and dynamic programming) and game theory (Agrawal and Heady). They are best adapted to normative problems in planning or choice. Given the end, they indicate the pattern of resource allocation or the selection among strategies which will maximize the objective desired.

A review of some of the applications of operations research, specifically mathematical programming, to farm-level decision making under both complete certainty and uncertainty will be discussed in this chapter.

Ranch Planning Under Conditions of Certainty

One of the earliest applications of linear programming to farm and ranch planning was conducted by Woodworth. This analysis considered the choice faced by ranchers of how to allocate a fixed number of animal units among two different ranges with different costs and production capabilities. The study concluded that the allocation derived from the linear programming model would result in a four percent increase in producer profits over that achieved by a random allocation.

The Woodworth study used the animal unit month method of allocating available forage over the production year. This method assumes that the animal has a constant intake requirement to meet its nutrient requirements. Thus, the only forage supply constraint incorporated in the model was that the number of animals multiplied by their respective feed requirements did not exceed the total dry matter production. The animal unit method assumes the total forage available can be distributed at will through the year without loss in quantity or quality. The static nature of this method can lead to obvious infeasibilities. The optimum forage system may produce an over-abundance of feed in one period of the year, and yet result in a serious forage deficit in another period.

A second example of the application of linear programming to ranch organization is a study conducted by D'Aquino. The objective of this study was to develop a methodology for representing the allocation of range resources in a static environment. The model simultaneously considered both forage and livestock activities in deriving optimal ranch plans. Seasonality of dry matter production was incorporated by dividing the year into five periods. The model was constrained to force the animal requirement or demand for protein, phosphorus and total dry matter to not exceed the amount produced during that period. Dry matter demand was assumed constant over the production period; thus, the analysis did not consider the variation in forage demand as forage quality changes.

The assumption of constant feed requirements overlooks an important relationship between forage quality and animal intake capacity. As forages mature, their digestibility decreases due to their increased lignin content (Maynard, Loosli, Hintz, and Warner). As the quality of a forage declines, an animal would have to increase its consumption rate in order to maintain a constant intake of digestible nutrients. This factor may require animals to exceed their intake capacity in order to meet nutrient specifications when a mature or low quality forage is the only source of feed. In addition to this phenomenon, there is the constraining effect that low quality forages have on an animal's digestive capacity. As the lignin content of a forage increases, the animal's rate of passage of a feed is slowed, reducing its intake capacity (Maynard, et al.). Due to these two factors, the animal consumes less total dry matter and obtains a lower level of nutrients per unit of consumption. As a result, the animal may be restricted from obtaining the necessary nutrients to maintain a specified rate of growth.

Bartlett, Evans and Bement contributed to D'Aquino's work, and thus the overall progression of linear programming applications to ranch planning, by introducing a recursive relationship between forage production periods. In previous work conducted by D'Aquino, once an acre of rangeland had been allocated to a period, any forage not consumed during that period was wasted. Bartlett et. al. used a serial model that allowed the remaining forage to be transferred into subsequent periods. The following continuity equation, describing the temporal allocation of a reservoir, is a simple way to explain the reasoning behind their transfer method (Roefs):

$$S_t + I_t - R_t = S_{t+1}$$

where,

S_t is reservoir storage at the start of time period t,

I_t is the inflow during period t, and

R_t is the release during period t.

This equation was adapted to forage production to demonstrate that the available forage at the beginning of period t, plus any growth and less any consumption during period t, resulted in the amount of forage available in the subsequent period (t+1).

In this serial model, it was implied that forage quality decreased with maturity of the plant, so that forage transferred from one period to the next was not necessarily transferred at the same level of quality. The study did not account for decomposition losses of the forage. After the point of "peak standing crop" has been reached, there are losses in the amount of total dry matter available for consumption (Engle, personal communication). The reservoir equation, which the study was based on, does not explicitly account for this loss.

A major advantage of the serial model over the previous static model developed by D'Aquino is that it allows the fixed resources to be used during different periods. In the static model, once a fixed resource (e.g., an acre of land) was allocated to a selected management activity, it could not be used in another. For example, if the activities are forage use during different seasons, a particular acre of rangeland could not be used during more than one season. If the season was a short-use period during the spring, the model could not specify any use of regrowth in the fall, since that area had already been allocated for spring use. Under this method, if different management activities are specified that represent all combinations of use (i.e., spring use, spring-summer use, spring-fall use, spring-winter use, spring-summer-fall use, etc.), the possible combinations are so numerous that the linear program becomes unwieldy. If the months of the year are considered as the grazing seasons, the number of combinations increases to 4,095. In general, the number of possible uses is 2^n-1, where n is the number of seasons. Through the use of Bartlett's serial model, the number of activities was increased to only 2n-1. This is due to the continuous flow as described in the "reservoir" equation as opposed to each season being an activity, exclusive of all other activities.

Jones developed a ranch-level linear programming model to evaluate alternative beef cattle and forage enterprises in eastern Oklahoma. Although it is not clear how intake restrictions were incorporated in the analysis, it appears the restrictions were constructed exogeneously. The total dry matter consumption capacity of an individual class of animals was determined, and the animal was allowed to consume only that amount. This capacity value was a general value without regard to the rate of passage of the feed being consumed. The forage quality-intake capacity relationship referenced earlier was not considered in developing the intake values.

Jones formulated the model to compare the balanced ration, total digestible nutrient, and animal unit techniques of specifying animal nutrient requirements. The model was used to determine the sensitivity of efficient farm organizations to the alternative nutrient specification methods.

The animal unit technique as described earlier was the least constrained of the three nutrient specifications. The only constraint used in this method was that subperiod intake by the herd not exceed the forage supply during the period. Variations in the forage quality through the season and its subsequent effect on animal intake capacity were not represented. Also, nutrient requirements were not factored into the forage supply-demand equation.

In the total digestible nutrient specification, a constraint on the nutrient needs of the animal was imposed. Total digestible nutrients (TDN) is a value which indicates the relative energy value of a feed to an animal. It is derived by adding the digestible crude protein, digestible crude fiber, digestible nitrogen-free extract and the digestible crude fat multiplied by 2.25 of a feed source (Cullison). According to Snapp and Newman, the production of energy to enable the body processes (growth, maintenance, etc.) is the prime purpose of feed. All organic nutrients can be used as energy; thus, energy value can be used as a rough estimate of the nutritive value of a feed. The fact that the organic nutrients, notably protein, may have specific and unique functions does not alter their usefulness as sources of energy.

The total digestible nutrient method possesses three major shortcomings in representing livestock nutrient requirements. First, TDN is not an actual total of the digestible nutrients in a feed since it does not include digestible mineral matter and digestible fat is multiplied by 2.25 before being included[1]. Second, as a result of the substitution effect of nutrient absorption, the TDN specification has no constraint to assure the specific nutrient needs of an animal are met (i.e., protein, phosphorus, etc.). The substitution effect refers to the ability of an animal to convert and use certain nutrients supplied in excess into the nutrient that is lacking (Maynard, et al.). This effect is variable and occurs at varying degrees of efficiency. Finally, the total digestible nutrient method does not account for intake limitations.

In the balanced ration technique, minimum total digestible nutrients and digestible protein constraints are included to assure that both of these nutrient requirements are met. Equally important is the inclusion of dry matter intake

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[1] This conversion is made to acount for the extra energy value of fats compared to protein and carbohydrates.

constraints which force the model to stay within the animals intake capacity while meeting its nutrient requirements.

This study pointed out the importance of including intake constraints while meeting animal nutrient requirements. In a comparison between the optimal solution generated by the three alternative nutrient specifications, the animal unit method was dominated by grasses. Less than one percent of the total available acreage was used for small grain forage production. In the solutions employing the total digestible nutrient and balanced ration technique, small grains became more important forage sources and grain supplementation was required for livestock grazing mature grasses. One would expect grasses to dominate small grains in a model that ignores quality considerations due to the relative advantage of grasses in terms of dry matter production. When the dry matter is required to be of a sufficient quality to meet nutrient requirements of different livestock classes, small grains become a more viable forage alternative. Use of the animal unit method resulted in deficient energy supplies in three of the six subperiods, and the animal's intake capacity was exceeded in all subperiods. Solutions derived using the total digestible nutrient method met the energy requirements of the animal, but exceeded the intake capacity in four of the six subperiods. Jones concluded that the balanced ration technique more closely represented the nutrient requirements of different classes of animals, and use of the other two techniques could result in serious infeasibilities.

Anderson and Walker used the balanced ration technique and indirectly included intake restrictions by allowing different classes of animals to consume only certain forage quality levels. Available forages were divided into three quality groups: those that had 2.36 to 2.8 megacalories of metabolizable energy per kilogram of dry matter (ME/Kg), those that had 2.01 to 2.35 ME/Kg, and those that had 1.71 to 2 ME/Kg. Next, the nutrient requirement of the animal was calculated, and the animal was allowed to consume only that quality of forage that would meet its requirements without exceeding its intake capacity. Individual rations were developed outside of the model, and the total requirement of each level of quality was calculated. The model then selected the optimum combination of forages to meet the predetermined forage quality and quantity demand.

Due to the preselected rations, the model is not provided the flexibility to determine the optimal combination of forages to use in feeding the selected animal classes. By exogenously developing the forage rations that can be used, one can effectively force the model to meet the animals nutrient requirement. However, the possible forage combinations that will meet the animals nutrient requirements are almost infinite and the model would soon become unwieldy in an attempt to include all combinations. By allowing the model to endogenously select any combination of feeds to meet the nutrient specifications you eliminate this problem is eliminated. In their study the intake constraints of each livestock class were added together to derive the forage demand for each respective period. The model then required forage supply to be equal or in excess of forage demand. By determining and constraining the nutrient requirements on a whole herd basis instead of by livestock class serious misspecification of the optimal livestock plan can occur.

Two subtle but very important problems are encountered with this method of calculating intake restrictions. By grouping the intake restrictions on a herd basis rather than by animal class, those animals that do not fill their intake capacities in satisfying their minimum nutrient requirements can, in essence, transfer their excess intake capacity to other animals. For example, if a cow is able to meet her nutrient requirements at a level considerably below maximum intake capacity, other livestock classes may exceed their actual intake constraints without violating the total herd intake constraint.

Another shortcoming of grouping forages into three quality categories concerns the wide range of forage quality that must be included in each category. According to this study, the intake capacities of each animal class are a constant value for each of the three forage classes. That is, there is no within class variation, even though there is variation in the forage quality in each group. Using intake equations developed by Dinius et al, as much as a 26 percent variation in the actual intake capacity of a 600 pound stocker exists within each of the forage quality classes.

Whitson, Park and Herd illustrated a method of including forage intake restrictions in a linear programming model to determine the impact of intake restrictions on the optimal linear programming solution. These researchers included constraints that required production of each forage per two-month period to equal or exceed the consumption during the same period. The forage combination that was selected also had to meet the nutrients requirements of the individual classes of animals without exceeding their intake capacities for each period.

In this study, the selection of the optimum ration to provide a preselected rate of gain was determined within the model. Also, instead of restricting intake on a herd basis, restrictions were specified for each class of livestock included in the model. This approach allowed observation of the effect of including intake restrictions for each of the different livestock classes included. This approach was taken to account for the different digestive capacities and nutrient requirements of the various livestock classes. Through the summation of total herd intake capacity, much of the precision of the intake constraint is forfeited.

Application of the model indicated that intake restrictions had a larger impact on optimal livestock rations as forage quality decreased. Supplemental feed requirements in the model's solutions were significantly higher than when the model was specified without intake restrictions.

Ranch Planning Under Conditions of Uncertainty

Quadratic Programming Applications

Each of the previously discussed studies were profit maximizing models that did not consider the certainty of obtaining a particular level of annual net income. Implied in these formulations is that prices and production can be determined with certainty. In reality, the rancher operates in an environment of uncertainty and is often willing to give up potential income in exchange for greater certainty of achieving a particular income level. The influence of risk on efficient livestock production systems may be incorporated through the application of risk programming procedures. Examples of risk programming to the analysis of efficient ranch organization include work done by Whitson; Musser, Shurley and Williams; Gebremeskel and Schumway; and Saez et al.

Whitson accounted for risk through the use of a quadratic programming model. Quadratic programming allows the user to quantify the tradeoffs between net income and the stability of that level of income. This non-linear programming technique had been used in investment analysis as early as 1959 by Markowitz. Through the use of quadratic programming, a series of "risk-efficient" ranch plans for a given resource base can be developed. The series is "risk-efficient" in that each ranch plan yields minimum income variance for alternative levels of expected income. These "risk-efficient" plans explain why two similar ranchers could be optimally organized and operate under different ranch plans.

The graphing of expected value and variance of net income derived from each plan in the series yields an expected income-variance (E-V) boundary (Figure 2). The highest point on the E-V boundary is the linear programming solution (point A), which consequently is a plan that produces the greatest net income and variance of income. Typically, as the profit maximizing point is approached, the level of risk is increased at an increasing rate; until in the vicinity of profit maximization, a small change in net income is associated with a large change in the stability of income. This ability to reduce risk substantially with little effect on expected net income demonstrates why the LP optimum solution is not typically the optimum solution for risk averse producers.

In the study conducted by Whitson, a set of alternative risk-efficient plans were developed. From the set of risk-efficient ranch organizations, the producer may select that management scheme which corresponds to his risk-return preference. The model was developed for a typical ranch firm situated in the Rolling Plains of Texas. Alternative livestock classes, stocking plans, retained ownership of weaned calves and different forage alternatives were evaluated to determine their effect on ranch income and its stability. The variance of income received from each alternative enterprise was obtained to monetarily value the uncertainty associated with each enterprise considered.

Typical managerial responses to reduce and/or cope with adverse effects of a dynamic and uncertain environment include the following actions: a) diversifying production, b) maintaining flexibility so that needed changes may be recognized and production adjusted, c) using marketing alternatives (i.e., futures, forward contracting) to reduce price variation, d) purchasing insurance, and e) holding ready reserves of cash and credit (Hopkin).

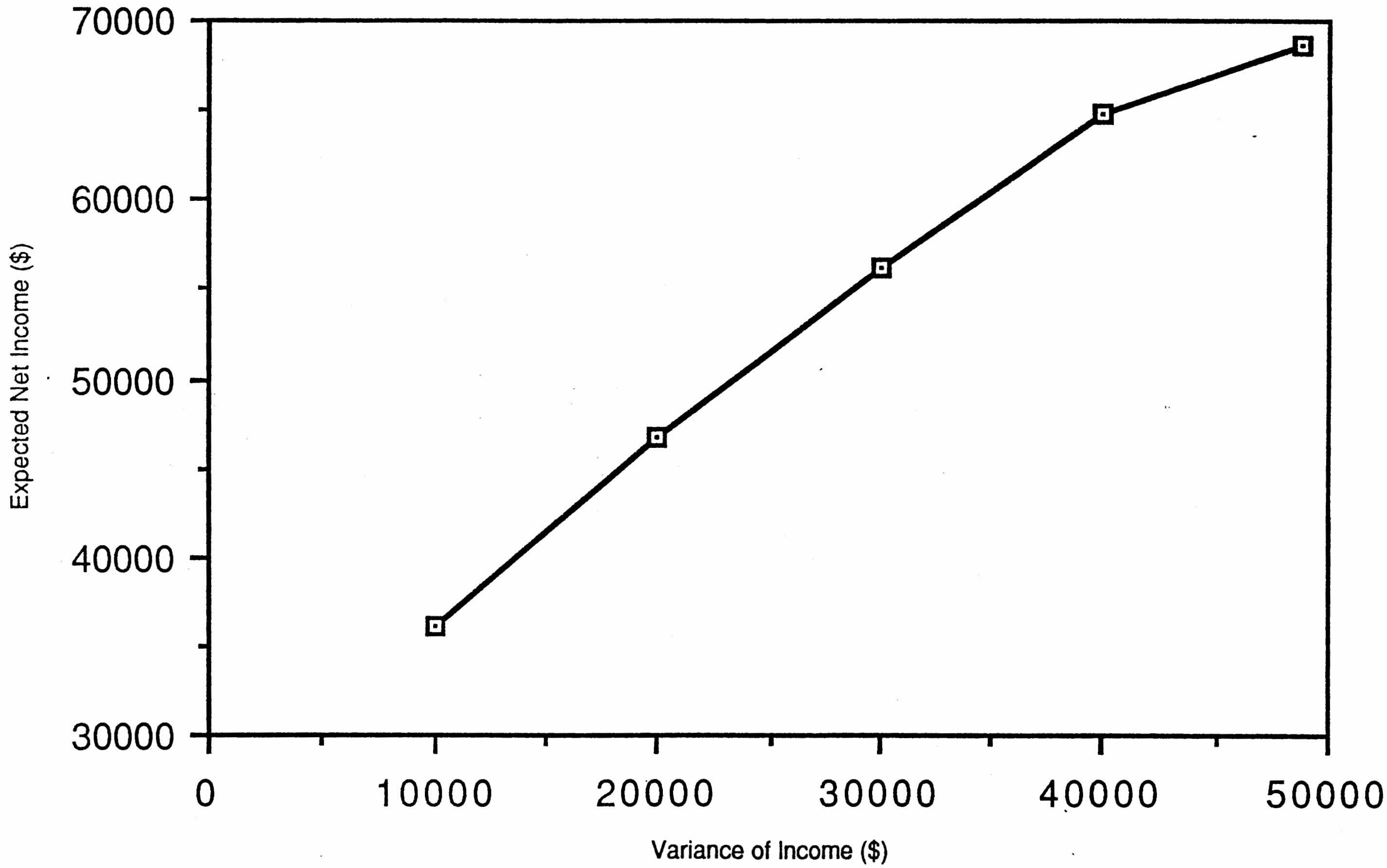

Figure 2. E-V Frontier

Through the use of quadratic programming these alternative methods of coping with risk were incorporated into the analysis and a set of alternative risk-efficient ranch plans were generated.

Diversification was included in the model by adopting alternative grazing systems such as a deferred-rotational grazing program as opposed to the typical continuous year- long grazing program. Other diversification alternatives included were the addition of stocker and feedlot activities to the traditional weaned calf phase of beef production. Through the use of quadratic programming these alternative methods of coping with risk were incorporated into the traditional economic analysis and a set of alternative risk-efficient ranch plans were generated.

To determine which ranch plan the typical rancher would select from among the alternative risk-efficient plans, a lexicographic objective function was specified. The use of a multiple goal objective requires that a) managerial goals or objectives be ordered and b) priorities for their attainment be established. The primary objective in this study was the attainment of a minimum "disaster" level of income with a predetermined probability; after this objective was met maximization of net income was then pursued. Through the use of a standard t table, and utilizing the standard deviation of net income determined from the quadratic programming analysis, the lower boundary of the net income confidence interval may be derived for each ranch plan. Given the risk-return objectives (increases in net income versus stability of net income) of the typical rancher, the "optimal" ranch plan in meeting this ranchers decision criteria can be selected. In this way resources are not necessarily allocated to maximize net income; rather they are allocated to maximize the ranch manager's objectives which include risk and return components.

Whitson pointed out that while the analysis method is a great improvement over the traditional linear programming model's approximation of the decision making process, there are several problems associated with its use. The major problems pointed out were: a) overcoming computational difficulties associated with the use of available computer programs (Batterham), b) determining the most important components of risk (Dillon and Anderson), c) measuring risk (Hazell), and d) considering input-output coefficients in the model as deterministic (Rae).

A second application of quadratic programming to ranch decision making was completed by Musser, Shurley, and Williams. This work analyzed the effect of production and marketing decisions for beef-backgrounding enterprises in Georgia. Backgrounding enterprises considered included alternative stocker grade, sex, and weight as well as including monthly buy and sell opportunities to allow alternative enterprise lengths.

The model was constrained to allow sufficient forage dry matter for the alternative livestock enterprises. Rations were determined exogenously to supply a sufficient plane of nutrition to allow a predetermined rate of growth. Thus, the model was not a whole-farm model, as no consideration of alternative forage or feeding activities were included.

The study was conducted to determine the portfolio effect of different selected backgrounding alternatives on risk and return. Each activity in the model was defined as one calf of a particular sex and grade bought on the fifteenth day of a specific month, fed a specific ration and sold on the fifteenth day of a future month. For each grade-sex combination, activities were defined for five purchase months, September through January. Each purchase month had three different sell periods four, five, and six months later. Three different grades were also considered, resulting in 45 alternative backgrounding activities.

The results of this study suggested an important implication for grading feeder cattle in the marketing system. Having the alternative to buy graded calves allows a producer to take advantage of portfolio effects available from seasonal supply and demand differences. In two of the three scenarios modeled, constraints were included to force specific ratios of the grade and sex of the animals purchased. The third scenario was unconstrained, allowing selection of animals of the desired grade and sex by the producer. Significant increases in income at alternative levels of risk were realized under the unconstrained scenario.

MOTAD Applications

While quadratic programming codes are commonly used to analyze alternatives in which both expected profit and risk are important parameters, the use of a quadratic programming algorithm is often troublesome. Hazell and Thompson demonstrated that linear programming can be used to approximate quadratic programming solutions if risks are defined using absolute deviations rather than variance. Hazell's "minimization of total absolute deviation" (MOTAD) linear programming model can be used to evaluate expected profit-risk tradeoffs in finding "risk-efficient" ranch plans. With quadratic programming the measure of income variance is only a statistical estimate of the true variance. This can lead to incorrect conclusions if the income distribution can not be accurately specified using the mean and variance. This problem is eliminated with the use of MOTAD since the actual sample absolute deviations are used. Another advantage to MOTAD relates to the computational advantages of solving large programming models with a linear programming, rather than non-linear quadratic programming algorithms.

Gebremeskel and Schumway used a MOTAD model in their work conducted in Texas. These researchers considered alternative forage and cattle management strategies including herd size, forage system, and cattle marketing plans to evaluate how ranchers could conceivably lower the level of risk associated with alternative levels of expected income. The model was formulated to meet the nutrient requirements of the cattle at a predetermined level of production. This was accomplished by first calculating the energy and protein requirements of each class of cattle via National Research Council procedures; then calculating the minimum quality of forage necessary to meet those requirements, for each of the six, two-month periods, without exceeding the animals intake capacity. The forages were divided into three different quality categories based upon their respective energy levels for the six different periods of each year. Lower quality forages than were required could be fed only if they were supplemented with concentrates to satisfy both the energy and protein requirements of the animal.

Gebremeskel and Schumway found that the expected income-mean absolute deviation (E-A) trade-off faced by the cow-calf producer is much steeper than that faced by typical crop-producers. The ability of livestock producers to reduce risk substantially with little effect on expected net return was attributed to a negative relationship between cattle prices and some forage yields, as well as the producer's ability to store forage for later use. They concluded that it would be difficult to conceive of a personal utility function that would cause a producer to prefer any solution other than the lowest risk-efficient plan. In addition, they reasoned that the traditional profit-maximizing LP solutions are unlikely to be adopted readily by cow-calf producers due to the fact that they include much higher risk levels with little improvement in expected net income. Consequently, ignoring risk in normative cow-calf production studies is a more critical oversight than in crop production studies.

Saez et al. extended the study conducted by Gebremeskel and Schumway to another study area in Texas to determine the effect of a different climatic region on the set of risk-efficient ranch plans. While Gebremeskel and Schumway used three locations extending from southeastern to central Texas, Saez et al. used two locations in the northeastern corner of Texas as the basis for their study area. Because of the geographical diversity of Texas, it was hypothesized that their may exist definite differences in the optimal organization of the risk-efficient ranch plans.

The majority of the conclusions found by Gebremeskel and Schumway were supported by this study. Both studies agreed that forage diversification had a much greater effect on reducing risk than did integration of the livestock activities. Gebremeskel and Schumway reported that spring calving was preferred to fall calving at all levels of risk. In addition, retention of weaned calves was preferred in the eastern portion of the study area, but was non-optimal in the western regions of the study area due to limited forage supplies. Saez et al. determined that fall calving was preferred at higher levels of risk; however, spring calving entered the efficient farm plans as risk was reduced. In addition, retention of weaned calves was preferred only if a spring calving scheme was used. A major difference in the conclusions of the two studies concerned the E-A tradeoff. Gebremeskel and Schumway found a very steep sloped E-A frontier (large changes in risk for a given change in expected income) for all cases considered. The conclusions of the study by Saez et al for east Texas found that a wide range of optimal feasible solutions were possible with a relatively small change in income variability.

These studies along with several others have demonstrated the potential of mathematical programming as a tool in whole-ranch analysis. In the past twenty years much progress has been made in taking the work from a purely theoretical standpoint to a level that can realistically portray the production and marketing alternatives facing a farmer/rancher. This study will further this work by considering different ranch management strategies for the typical eastern Oklahoma livestock producer.

CHAPTER III

METHOD OF ANALYSIS

Theoretical Derivation of Linear Programming

This study is concerned with determining an optimal livestock farm organization, given a specified amount of land, capital and other assumptions concerning available farm resources and productivity levels. Theoretically, the farm firm allocates resources until the cost of the last unit of input is equal to the revenue produced by the corresponding output (Ferguson and Gould). That is, the fixed resources (land, operator labor, management, etc.) are allocated to the most profitable activities to the point that a change in resource allocation among the activities cannot increase returns. Variable inputs (e.g., nitrogen, stockers, hired labor, etc.) are allocated to production as long as additional returns cover additional costs.

Linear programming utilizes the same concepts of marginal analysis for determining the optimal allocation of resources to the activities producing the greatest return. The objective of the linear programming model is to find the farm plan that has the largest possible total gross margin subject to the limited resources available to the farm decision-maker. Linear programming accomplishes this task by selecting that combination of activities that provides the highest return, gross margin or other specified objective with the specified constraints.

To accomplish this objective, the linear programming model requires specification of:

resource requirements, and any specific constraints on their production, b) the fixed resource constraints of the farm and c) the forecasted net returns of the alternative activities.

The standard farm-level linear programming model can be written as:

$$\max Z = \sum_{j=1}^{n} C_j X_j$$

subject to

$$\sum_{j=1}^{n} a_{ij} X_j \leq B_i \qquad (i=1, 2, \ldots, m)$$

$$X_j \geq 0 \qquad (j=1, 2, \ldots, n)$$

where,

X_j is the level of the j^{th} farm production activity.

C_j is the forecasted net return of a unit of the j^{th} activity.

n is the total number of possible production activities.

a_{ij} is the quantity of the i^{th} resource required to produce one unit of the j^{th} activity.

B_i is the amount of the i^{th} resource available.

m is the total number of resources available.

A brief description of the assumptions underlying LP models is useful to gain a clear insight of the advantages and limitations of the model. These assumptions are:

1. Additivity of resources and activities: the activities are assumed to be additive in the sense that when two or more are used, their total product is the sum of their individual products. That is, no interaction effects between activities or resources are permitted.
2. Divisibility of activities and resources: resources can be used and activities produced in quantities that are fractional units. This implies continuity of resources and outputs.
3. Finiteness of the activities and resources: there exists only a finite number of activities and constraints to be considered.
4. Proportionality of activity level to resources: the resource requirements per unit of activity are assumed constant regardless of the level of activity used. This implies a Leontief production function.
5. Single-value expectations: resources availability, input-output coefficients, prices, and other variables are known with certainty.
6. Linearity of the objective function: net revenues or total cost of each activity remains constant, regardless of its quantity in the optimal solution.

For a detailed discussion of mathematical programming, the reader is referred to Taha, Hazell and Norton, or Hadley.

Derivation of MOTAD

There have been various alternative methods developed to incorporate risk into an analysis of the firm-level decision making process. The MOTAD model has been selected for this study to evaluate alternative cattle production systems, including livestock enterprises, herd size, forage systems, and marketing strategies, due to the sound theoretical foundations on which the method is based as well as the practical advantages in overcoming computational difficulties. The ultimate goal is to reach a series of optimal firm-level beef and forage production systems and optimum cattle marketing options for a long-run period.

The MOTAD model makes it possible to satisfy a risk objective in a linear programming model by linear approximation. Using absolute income deviation (A) as a measure of risk, Hazell assumed that a decision maker may consider both expected income (E) and A as the critical parameters in the selection of a farm plan. Efficient E-A farm plans are those having minimum absolute income deviation for given expected income levels.

The MOTAD model minimizes the deviations between the expected income and income arising under the various states of nature. If there are K states of nature, then the absolute deviation of income from the expected value under the Kth state of nature is:

$$D_K = | \sum_j C_{Kj} X_j - \sum_j \bar{C}_j X_j |$$

where,

C_{kj} is the level of returns associated with the j^{th} activity in the K^{th} state of nature.

X_j is the level of the j^{th} farm production activity

$\bar{C}_j$ is the expected income

Since both terms contain X_j and the summation is over the same range, this expression can be simplified to:

$$D_k = | \sum_j (C_{Kj} - \bar{C}_j) X_j$$

Assuming that the above equation is denoted as D_K, the total absolute deviation is the sum over K. Let the deviation in income from its mean in the k^{th} state of nature be denoted by d_K^+ if positive, and by d_K^- if negative. Then, total absolute deviations (TAD) may be calculated as:

$$TAD = \sum_K D_K = \sum_K (d_K^+ + d_K^-)$$

The MOTAD model then maximizes the expected value (E) less some risk aversion coefficient (λ) times the TAD.

That is,

$$\text{Maximize } E - \lambda TAD = E - \lambda \sum_K D_K = E - \lambda \sum_K | (C_{Kj} - C_j) X_j$$

Through substitution the expression may be respecified as:

$$\text{Maximize } E - \lambda \sum_K (d_K^+ + d_K^-)$$

$$d_K^+ - d_K^- - \sum_K (C_{Kj} - C_j) X_j = 0 \text{ for all } K$$

$$X_j, d_K^+, d_K^-, \geq 0$$

If X_j is constrained by whatever other relevant constraints there are on X, the final MOTAD model then becomes:

$$\text{Maximize } \sum_j C_j X_j - \lambda \sum_K (d_K^+ + d_K^-)$$

subject to

$$\sum_j a_{ij} X_j \leq b_i \quad \text{for all } i$$

$$\sum_j e_{Kj} X_j - d_K^+ + d_K^- = 0 \quad \text{for all } K$$

$$X_j, d_K^+, d_K^-, \leq 0$$

where,

e_{Kj} is the deviation from the value expected for the j^{th} variable under the K^{th} observation ($e_{Kj} = C_{Kj} - C_k$).

d_K^+ is the positive deviation of the K^{th} income occurrence from mean income.

d_k^- is the negative deviation under the K^{th} observation.

Hazell recognized that in considering the MOTAD model as a substitute for quadratic programming in the development of efficient E-V farm plans, it is necessary to accept some loss in the reliability of the results. Fisher has shown that for large sample sizes the mean absolute deviation is only 88 percent as efficient as the standard deviation in estimating the population standard deviation. As quadratic programming utilizes the most efficient estimator of variance, it is subject to the least expected error. However, both models use the same estimate of E.

More recently, Thompson and Hazell found that the usefulness of the MOTAD model could be greater than previously thought because the essential problem is to find the most efficient plan in terms of ranking equal-income plans by V, rather than to estimate its parameters. They also concluded that the MOTAD model performed better than quadratic programming when the return distributions are of the mixed-normal or chi-square form. Consequently, it seems reasonable to conclude that the MOTAD model may have considerable potential as an alternative procedure to quadratic programming in deriving E-V farm plans. In addition, the MOTAD model through the use of a standard linear programming algorithm, may also lead to much smaller problems for complex farm organizations and is better adapted for post-optimality analysis.

The Analytical Model

For this study, the model is specified in the form of maximizing expected net returns subject to parametric restrictions on the mean absolute deviations in net return. This is equivalent to Hazell's specification. In this case however, instead of minimizing absolute deviations for different levels of income as Hazell specified, expected net income is maximized subject to various amounts of risk. The MOTAD formulation employed may be written in generalized form as:

a) $$\max Z = \sum_{j=1}^{m} C_j X_j$$

subject to

b) $$\sum_{j=1}^{m} A_{ij} X_j \leq B_i \quad (i=1,2,\ldots,m)$$

c) $$\sum_{j=1}^{m} (C_{Kj}-G_j)\, X_j - Y_K^{+} + Y_K^{-} = 0 \quad (k=1,2,\ldots,n)$$

d) $$1/s \sum_{k=1}^{s} \sum_{j=1}^{m} |Y_{Kj}| \leq \lambda$$

e) $$X_j,\ Y_K^{+},\ Y_K^{-} \geq 0$$

where,

Z is the expected objective function or net income.

C_j is the average or expected income values for the K^{th} production activity.

X_j is the the level of the j^{th} production activity.

B_i is the constraint levels imposed on the production activities.

m is the the total number of resources available.

n is the the total number of possible production activities.

Y_K^+, Y_K^- are positive or negative income deviations:

$$\left| \sum_{j=1}^{m} (C_{Kj}-G_j)X_j \right|$$

G_j is the sample income mean of activity j.

A_{ij} is the technical coefficient representing the quality of resource i used in the production of one unit of activity K.

λ is a scaler representing the allowed absolute deviation in income for each alternative farm plan.

Both the objective function (a) and constraint (b) are identical to a standard linear program formulation. Constraint (c) is used to direct the model to select the combination of alternatives that minimizes absolute deviations for each level of net income. Constraint (d) adds all deviations (positive and negative) and computes the mean absolute deviation. The last inequality (e) simply constrains the variables X and Y to nonnegative values.

By parameterizing λ, a frontier of E-A efficient farm organizations may be derived. From the E-A frontier,important information concerning the risk-return properties of various production plans can be derived. A straight line between two points implies that the same activities are entering successive plans and using resources in a given proportion. This results in linear changes in production, net return (E) and total negative deviation (A). Thus, it can be concluded that two successive segments of the E-A frontier which have different slopes include plans that are different with respect to one or more of the production activities and/or proportion of resource use. The change in farm plans occurs at the point of slope change. The E-A frontier is used to approximate a smooth E-V frontier and is actually a stepped curve consisting alternately of horizontal and vertical segments with changes in plans occurring at basis change. Several basis changes may actually occur between each of the points reported on the E-A frontier. However, for simplicity, only a few of the points on the E-A frontier are typically reported.

The slope of an E-A frontier is expressed as $\Delta E/\Delta A$. That is, the slope of the boundary may be expressed in terms of the change in expected total net returns (E) associated with each unit change in total negative deviations (A). The slope of the E-A frontier is an estimate of the amount of risk reduction associated with each dollar in net returns that the producer is willing to forego. The slope increases as both E and A decrease with movement down the frontier. Therefore, comparisons can be made between two plans on the basis of how rapidly the slope increases from one critical point to another. Also, comparisons can be made between plans for different scenarios.

Description of the Analytical Model

An abbreviated tableau of the linear programming model is presented in Table I. Because forage production, forage quality, and animal nutrient requirements differ substantially over time, the year is divided into six two-month subperiods. For ease of illustration, the tableau presented in Table I includes only two subperiods, as well as two forage and two livestock activities (stockers and cow-calf). Selected symbols are used in the tableau to represent the actual numerical values that are in the model. Superscripts and subscripts are used to

TABLE I

ABBREVIATED TABLEAU OF MOTAD MODEL

	Forage Activities		Livestock Activities: Cow-Calf Consumption				Livestock Activities: Stocker Consumption				Livestock Activities: Requirements		Sell Activities		Hay Deviations: Purchase				Hay Deviations: Sell				Net Return Deviations: Positive		Net Return Deviations: Negative		
			Forage A		Forage B		Forage A		Forage B						Year 1		Year 2		Year 1		Year 2						
	A	B	1	2	1	2	1	2	1	2	C-C	Stk.	C-C	Stk.	1	2	1	2	1	2	1	2	Year 1	Year 2	Year 1	Year 2	
0) Objective Function	$-C_a$	$-C_b$									$-C_c$	$-C_s$	$+C_{sc}$	$+C_{ss}$	$-C_{11}$	$-C_{12}$	$-C_{21}$	$-C_{22}$	$+C_{11}$	$+C_{12}$	$+C_{21}$	$+C_{22}$					
1) Acres	1	1																									$\leq b_2$
2a) Forage A, Period 1	$-P_{a1}$		T^c_{a1}				T^s_{a1}																				≤ 0
b) Forage A, Period 2	$-P_{a2}$			T^c_{a2}				T^s_{a2}																			≤ 0
c) Forage B, Period 1		$-P_{b1}$			T^c_{b1}				T^s_{b1}																		≤ 0
d) Forage B, Period 2		$-P_{b2}$				T^c_{b2}				T^s_{b2}																	≤ 0
3a) Energy, Cow-Calf, Period 1			$-M^c_{a1}$		$-M^c_{b1}$						E^c_{e1}																≤ 0
b) Energy, Cow-Calf, Period 2				$-M^c_{a2}$		$-M^c_{b2}$					E^c_{e2}																≤ 0
c) Protein, Cow-Calf, Period 1			$-R^c_{a1}$		$-R^c_{b1}$						E^c_{p1}																≤ 0
d) Protein, Cow-Calf, Period 2				$-R^c_{a2}$		$-R^c_{b2}$					E^c_{p2}																≤ 0
4a) Energy, Stockers, Period 1							$-M^s_{a1}$		$-M^s_{b1}$			E^s_{e1}															≤ 0
b) Energy, Stockers, Period 2								$-M^s_{a2}$		$-M^s_{b2}$		E^s_{e2}															≤ 0
c) Protein, Stockers, Period 1							$-R^s_{a1}$		$-R^s_{b1}$			E^s_{p1}															≤ 0
d) Protein, Stockers, Period 2								$-R^s_{a2}$		$-R^s_{b2}$		E^s_{p2}															≤ 0
5a) Intake, Cow-Calf, Period 1			1		1						-1																≤ 0
b) Intake, Cow-Calf, Period 2				1		1						-1															≤ 0
c) Intake, Stockers, Period 1							1		1		-1																≤ 0
d) Intake, Stockers, Period 2								1		1		-1															≤ 0
6) Calf Transfer											-1		1														≤ 0
7) Stocker Transfer												-1		1													≤ 0
8a) Forage Deviation, Yr.1, Pd.1	d^a_{11}	d^b_{11}													1960				-1960								$= 0$
b) Forage Deviation, Yr.1, Pd.2	d^a_{12}	d^b_{12}														1960				-1960							$= 0$
c) Forage Deviation, Yr. 2, Pd. 1	d^a_{21}	d^b_{21}															1960				-1960						$= 0$
d) Forage Deviation, Yr. 2, Pd. 2	d^a_{22}	d^b_{22}																1960				-1960					$= 0$
9a) Return Deviation, Year 1	r_{a1}	r_{b1}									r_{d1}	r_{e1}	r_{c1}	r_{s1}	r_{11}	r_{12}	r_{21}	r_{22}	r_{11}	r_{12}	r_{21}	r_{22}	-1		+1		≤ 0
b) Return Deviation, Year 2	r_{a2}	r_{b2}									r_{d2}	r_{e2}	r_{c2}	r_{s2}	r_{11}	r_{12}	r_{21}	r_{22}	r_{11}	r_{12}	r_{21}	r_{22}		-1		+1	≤ 0
10) Risk																							.5	.5	.5	.5	$\leq \lambda$

designate the period of use and the forage and livestock activities that are being represented by the symbol.

Row 0 represents the costs and revenues associated with each respective activity (C_{ij} values in Table I). Production costs as well as the returns from selling the commodities produced (i.e., stockers, weaned calves, hay, wheat, etc.) are included. No constraint is set on this row as this is the objective function row which will be maximized at an associated level of risk.

Row 1 represents the land constraint of the model ranch. This row specifies that the sum of all acres used in the production of the alternative forages cannot exceed the total number of acres available to the farm manager. Each forage activity is calculated on a per acre basis, and no double cropping of the land base is permitted.

Rows 2a through 2d are used to represent the different forage production and consumption coefficients in pounds of air-dry forage by two-month subperiod. A consumption-production constraint is included for each subperiod and includes all alternative livestock consumption coefficients for that subperiod. Forage production (P_{ij} values in Table I) and consumption (T_{ij} values) are constrained so that total consumption of a particular forage by all livestock activities cannot exceed the total availability of dry matter of that forage type during that subperiod.

A modified version of a formulation introduced by Whitson, Park and Herd (Chapter II) is used to represent forage intake and quality considerations. Intake equations developed by Dinuis are used to estimate the total dry-matter consumption capacity of each livestock class for each specific forage during the six subperiods. Consumption coefficients indicating maximum subperiod intake are denoted as T's in the tableau and are based upon animal size and forage quality. Equations employed to estimate these values are explained in the nutrient requirement section of Chapter IV.

Rows 3a through 4d represent the nutrient balance constraints for each alternative livestock class. Energy, protein and intake constraints developed using NRC equations are included in the model for each livestock activity. Megacalories of metabolizable energy (M_{ij}) and pounds of crude protein (R_{ij}) supplied by the ingested level of each individual forage by the specific livestock class are used to measure nutrient requirements. The level of nutrients supplied by the intake of the respective animal is forced to meet or exceed the nutrient requirement for the respective livestock class during each subperiod that the animal is consuming forage. An energy, protein and intake constraint was included for each livestock class during each subperiod to assure that no intake constraint was exceeded in meeting the minimum individual class nutrient requirements. The nutrient requirements are represented by an E, with a subscript e denoting the megacalories of metabolizable energy required and a subscript p denoting the pounds of crude protein required. All supply and demand values are based on the requirement for the sum of the two month subperiod. If a particular forage is not capable of meeting the animals nutrient requirements during a specific subperiod, the model forces the animal to be supplemented with the most economical nutrient source that will meet the requirement. This feed source can be either protein supplement or a higher quality forage. However, the sum total of all feeds consumed cannot exceed the animals intake capacity.

Rows 4a through 4d are analogous to rows 3a through 3d, but represent the nutrient requirements of the stocker enterprise. These constraints are included to illustrate the need for a different set of nutrient constraints and forage intake rows for each alternative livestock class during each subperiod.

Without alternative constraints for each livestock class during different seasons of the year, maximum intake constraints and/or minimum nutrient constraints can be violated.

An independent set of intake constraints (row 5) are specified for each livestock activity to require the model to meet the animals nutrient requirements without exceeding its intake capacity. These rows allow any combination of the feeds available in each subperiod to be consumed by the animal. The sum of the respective portions of the animals diet are constrained so that the sum total of the animals consumption is not greater than its intake for the subperiod.

Rows 6 and 7 represent two of the transfer activities included in the model. These rows allow the model to transfer the end product of each respective stage of production to the next stage of production or to sell them. Weaned calves can either be sold at weaning or transferred to a stocker activity which represents a form of retained ownership. This allows the model to select between retaining on-farm calves for the various stocker activities, purchasing stockers or a combination of both. In the full model, values less than one were used in the transfer rows to represent the death loss or weaning percentage associated with each livestock activity.

Transfer rows are included for all livestock activities to represent the option to sell or purchase livestock during all seasons of the production year. In addition transfer rows are included to allow any forage that is not consumed during a specific subperiod to be transferred to the next subperiod. If forage is transferred into a later subperiod it can only be consumed at a lower quality value, consistent with the subperiod in which it is consumed. Thus, it is necessary to exclude the transfer of mature forage to a subperiod in which new growth is occuring.

Forage yield variability between years is represented as deviations from the average yield in row 8a through 8d. Average subperiod production for the six year period is calculated for each forage, and the deviations represent the positive and negative deviations for each of the subperiods. Thus, in the full model forage deviations are represented using 36 rows (6 years X 6 subperiods). In order to correctly value yield deviations of the alternative forages, it is necessary to express them on a common basis that equates the deviations. To accomplish this, dry matter deviations were converted to deviations in megacalories of energy supplied during each subperiod (d_{ij} values). Deviations in forage supplies between years are converted to a monetary value by valuing the megacalories in excess or shortage. Prices paid and received for hay in Oklahoma were used to determine the value of the energy supplied by the alternative forages.

Seasonal deviations in net returns are calculated in row 9. Row 9 represents the net return deviations resulting from variability in the prices of beef and selected inputs used in the stages of production. Values are included in this row for activities which have variability in their cost of production or the returns generated by their production (i.e., fertilizer, protein supplement, stocker calves). In the full model, a return deviation row is included for each of the six years comprising the data set.

The sum of the positive and negative net return deviations are then transferred to row 10 where risk is represented. Positive and negative deviations for each of the six years have an equal probability of occurring and are weighted accordingly. This is accomplished by assigning each deviation a probability of .167 (1/6). The sum of all deviations weighted by the probability of their occurrence gives the risk factor or mean absolute deviation from the expected income. The right-hand-side of this constraint may be parameterized to trace out the E-A frontier of efficient ranch organizations.

For ease of illustration some factors of the actual model were not represented in the abbreviated tableau. Labor accounting rows were included in the full model to value any labor supplied by the operator or hired labor. No limit was set on the number of hours of labor that could be purchased, but each hour of labor employed was paid from the net revenues. The labor associated with each activity was summed by subperiod and the total amount of labor in each subperiod was billed to the objective function.

Capital accounting was included in the model to determine the amount of operating capital necessary to borrow in order to implement the production plan. Borrowed money was charged an interest cost based upon the time for which funds were held. Interest costs associated with the capital requirements of the different production activities were included in the objective function coefficient (C_{ij}) of the specific activities. These costs were valued at the opportunity cost of the capital used during the production period.

Bermuda hay and protein supplement feeding activities were included in the full model in a manner similar to the forages. The intake limits for both supplemental feeds were calculated for each livestock activity and the associated energy and protein supplies were derived. It was assumed that both bermuda hay and protein supplement could be fed in any of the six subperiods, and no limit was put on the total amount of either that could be purchased. This specification allows the model to meet the nutrient requirements of any of the livestock activities by supplemental feeding during periods of forage deficits.

Finally, an activity was included in the full model to allow bermuda forage to be harvested as hay. Due to dry matter losses during hay production, 1.11 pounds of standing forage are required for each pound of hay produced

(Huhnke, personal communication). It is assumed that hay production can take place only in the fourth subperiod, July-August, which is consistent with the season when a majority of the hay is harvested in the study area. The hay that is produced in this manner can either be sold or consumed on the farm.

Research Assumptions

The principle assumptions associated with the development and use of the efficient E-A frontier are essentially identical to those required for the E-V rule (except that mean absolute deviation replaces the variance concept). These assumptions can be stated as:

a) The only relevant variables that enter the decision making process are the expected returns and the variation of the returns around their expected value.

b) The decision maker is assumed to be risk averse. That is, he will prefer less risk to more risk given the same monetary outcome.

c) Returns for any given activity are independently distributed through time. This assumption requires, for example, an absence of weather and price cycles and no significant trend in prices or technology.

CHAPTER IV

DATA REQUIREMENTS AND DESCRIPTION

This chapter specifies the production requirements and assumptions used in the model. First, the assumptions and alternative cattle production schemes are detailed followed by the pasture and feed specifications for the alternative feed sources. Information in the study is based on data from research stations in the area. In those situations where the necessary data were missing extrapolations were made from the available data. Explanations of the methods used are unique in each instance and thus, are explained as they occur.

Breed

A Brahman-Hereford beef cattle herd is assumed for this study. By crossbreeding Brahman cattle with the British breeds the heat and insect tolerance of the Brahman can be combined with the desired carcass characteristics, including carcass grade and tenderness, of the British breeds. This, combined with the beneficial effects of heterosis on survival and growth of calves, and fertility and maternal characteristics of cows, has resulted in crossbreds that are well-adapted for beef production in the Southern Region (Cundiff and Gregory).

It is assumed that the breeding herd of crossbred Brahman Hereford cows are maintained through a rotational crossing. In the simple two-breed rotation assumed here, the cows of breed A are bred to bulls of breed B.

Heifers resulting from this cross are mated to bulls of breed A. In the next generation, the heifers from bulls of breed A are bred to bulls of breed B. This rotation continues from generation to generation, and it is only necessary to identify heifers by the breed of their sire.

Calving Season

The time of calving is a matter of the cattleman's choice. Usually the commercial cattleman tries to have his cows calve at a time when pasture and weather conditions are the most favorable, typically early spring or fall. Spring calving is usually scheduled to occur after the inclemencies of winter have past, but prior to the heat of summer and subsequent fly problems. Those cows that calve in the fall are usually bred so that calving is completed prior to harsh winter weather. The greatest percentage of cattle born in the United States are born in the spring (Neumann); however, some farmers, especially in the central and southern states, find it advantageous to calve in the fall. The advantage of spring calving is the ability to produce heavier calves under extensive, rather than intensive, methods of cattle production (Neumann).

Since both fall and spring calving seasons are physically feasible in eastern Oklahoma, their economic feasibility was considered as alternative activities in the mathematical programming model. For the purpose of this study it was assumed that spring calving will center on April 1 and fall calving will center on October 1.

Replacements

It was assumed that the farm produces its own replacements; therefore, a portion of the weaned heifers are retained to enter into the breeding herd. Twelve heifers are retained annually for each 100 cows in the herd. These heifers are bred at 15 months of age so that they will calve as two-year olds. They will be retained on a nutritional plane after weaning that will allow them to weigh 1000 pounds when they calve. This will require an average daily gain of 1.05 pounds for fall heifers weaned at 285 days and 1.21 pounds for fall heifers weaned at 210 days. Spring heifers weaned at 210 days will gain 1.11 pounds per day in order to reach their mature weight. Mature cows will maintain an average weight of 1000 pounds for the remainder of their productive life.

Cow Herd Composition

The composition of the cow herd is one of the most critical factors that determine the efficiency of production. Herd composition assumptions affect feed and pasture requirements across the year, as well as receipts and expenses. Some of the principle factors influencing this herd composition are conception rate, death rate and culling practices used. The values of these factors give a good indicator of the level of management employed by the ranch manager. For this study it is assumed that a high level of management is realized. The objective of this study is to determine the long-run optimal ranch organization for the firm. During the long run, one could reasonably expect the management ability of producers to improve and realize a higher level of expertise. Thus, the results of this study will reflect the potential output and net returns rather than those currently achieved. Even under good management, however, some loss of efficiency is normal due to failure to breed and death losses of cattle at different stages of their life. These normal inefficiencies are reflected in the production parameters employed.

Details of the annual herd dynamics for the cow activities are shown in Tables II and III. Under the culling and replacement assumptions used, during the year a 100-head cow herd has 66-71 cows four years old or older, 11 three-

TABLE II

COW HERD DYNAMICS FOR A 100 HEAD COW HERD; 210 DAY WEANING

	------Breeding------				--------Weaning--------					----Calving----			Totals
Month	1	2	3	4	5	6	7	8	9	10	11	12	
Spring Calving	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
Fall Calving	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mature Cows	92	92	92	92	82	82	82	81	80	92	92	92	80.75 Ave
Sell				10									10
Die								1	1				2
Replacement Heifers	12	12	12	12	24	24	24	24	24	12	12	12	17 00 Ave
Heifer Calves	44	44	44	44	0	0	0	0	0	45	45	44	
Sell				32									32
Die												1	1
Steer Calves	44	44	44	44	0	0	0	0	0	45	45	44	
Sell					32								32
Die												1	1
Bulls	4	4	3	3	3	3	3	3	3	3	4	4	3.30 Ave
Sell			1										
Buy											1		
Total Cows	104	104	104	104	94	94	94	93	92	92	92	104	97.60 Ave

Adapted from Walker, Lusby and McMurphy, 1987.

TABLE III

COW HERD DYNAMICS FOR A 100 HEAD COW HERD; 285 DAY WEANING

	Breeding				Weaning					Calving				Totals
Month	1	2	3	4	5	6	7	7	8	9	10	11	12	
Calving	Jan	Feb	Mar	Apr	May	Jun	Jul	Jul	Aug	Sep	Oct	Nov	Dec	
Mature Cows	92	92	92	92	92	92	92	82	81	80	92	92	92	89.7 Ave
Sell								10						10
Die									1	1				2
Replacement Heifers	12	12	12	12	12	12	12	24	24	24	12	12	12	14.5 Ave
Heifer Calves	44	44	44	44	44	44	0	0	0	45	45	44		
Sell							44						32	
Die												1	1	
Steer Calves	44	44	44	44	44	44	0	0	0	45	45	44		
Sell							44						44	
Die												1	1	
Bulls	4	4	3	3	3	3	3	3	3	3	3	4	4	3.3 Ave
Sell			1											
Buy												1		
Total Cows	104	104	104	104	104	104	104	94	93	92	92	92	104	99.7 Ave

Adapted from Walker, Lusby and McMurphy, 1987.

year old cows and 12 two-year old cows. Cows exit the herd by culling (10 percent) or by death (2 percent). Culling of cows takes place after weaning in all of the cow activities. The calving rate was assumed to be 90 percent of a 100 cow herd. However, the calves born per cows and heifers bred is (90/104) or 86.5 percent. Due to those animals which do not conceive, it is necessary to breed more than 100 cows for a "100 cow herd". There are 104 cows used in calculating the calves born per bred cows to account for the 10 cows which will be culled and the 2 cows which are assumed to die. Two calves die per 100 head of cows prior to weaning. Assuming an equal number of steers and heifers are calved, 44 steers and 44 heifers are weaned per 100 head of cows. All of the steer calves are available for sale or retention into a stocker program, while only 32 of the heifers are available due to brood cow replacement needs.

During the breeding season, one bull is kept for every 25 cows. When the breeding season is over, 25 percent of the bulls are culled and replaced prior to the next breeding season. When bulls are first purchased their average weight is 1300 pounds. The bulls are assumed to gain 0.5 pounds per day for the 40 months they are in the herd and are sold at an average weight of 1900 pounds. Average bull weight used in computing the feed requirements is 1600 pounds. Bull entry and exit is illustrated in Tables IV and V. The table is designed to illustrate the entry and exit of one bull from a 100 head cow herd; thus, their are four bulls in the herd. Typically, a one year old bull replaces the four year old bull each year.

Retained Ownership and Purchased Stocker Activities

Alternative livestock activities and their marketing options are depicted graphically in the schematic flow charts in Figures 3 and 4. Also, Table VI lists the assumptions used for the alternative stocker enterprises (i.e., average daily

TABLE IV

BULL DYNAMICS FOR A 100 HEAD COW HERD-FALL CALVING

	-Month-											
Bull Slot	J	F	M	A	M	J	J	A	S	O	N	D
1	X	S	O	O	O	O	O	O	O	B	X	X
2	X	X	X	X	X	X	X	X	X	X	X	X
3	X	X	X	X	X	X	X	X	X	X	X	X
4	X	X	X	X	X	X	X	X	X	X	X	X

B = bought; S = sold; X = in herd; 0 = slot empty that month
Adapted from Walker, Lusby and McMurphy, 1987.

TABLE V

BULL DYNAMICS FOR A 100 HEAD COW HERD-SPRING CALVING

	Month											
Bull Slot	J	F	M	A	M	J	J	A	S	O	N	D
1	0	0	O	B	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X	X	X	X	X
3	X	X	X	X	X	X	X	X	X	X	X	X
4	X	X	X	X	X	X	X	0	0	0	0	0

B = bought; S = sold; X = in herd; 0 = slot empty that month
Adapted from Walker, Lusby and McMurphy, 1987.

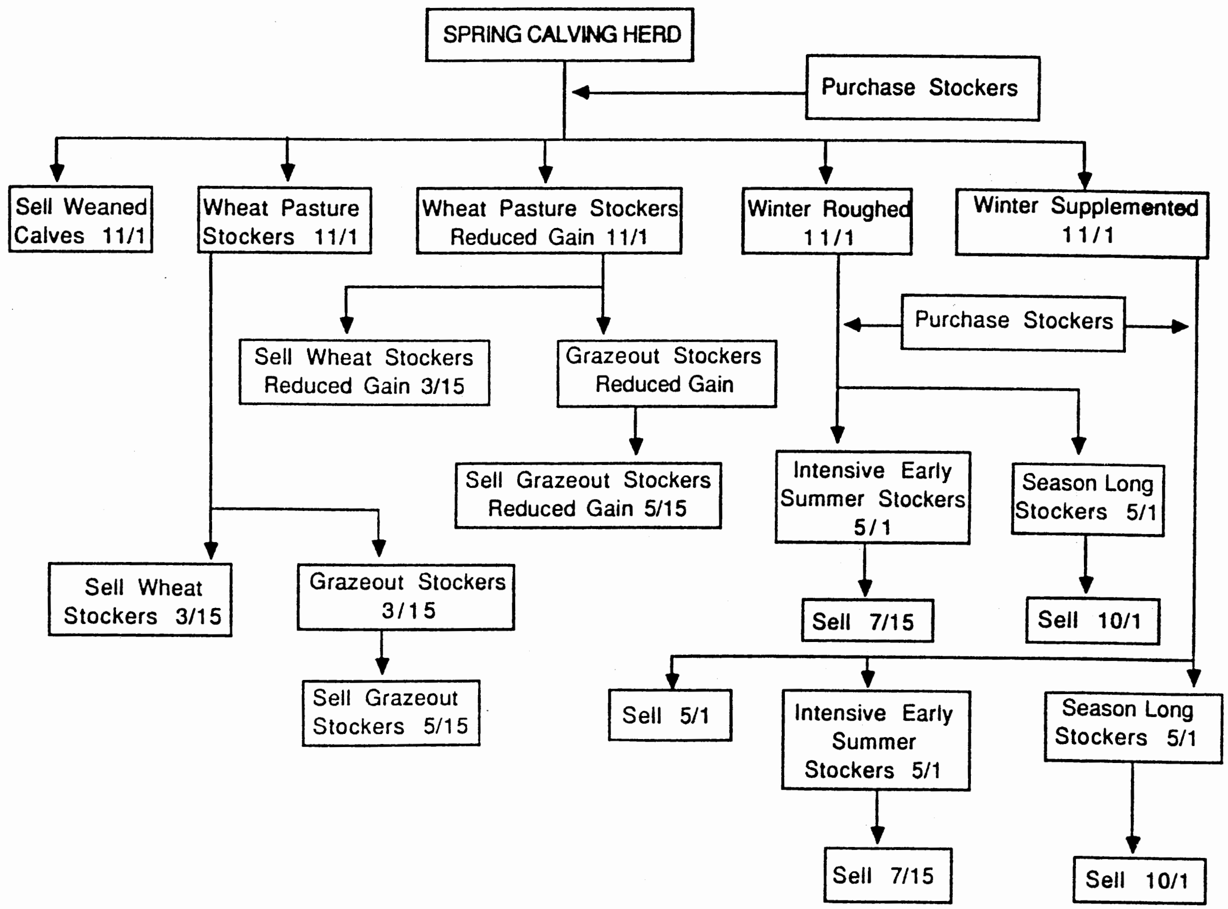

Figure 3. Spring-Calving Flow Chart

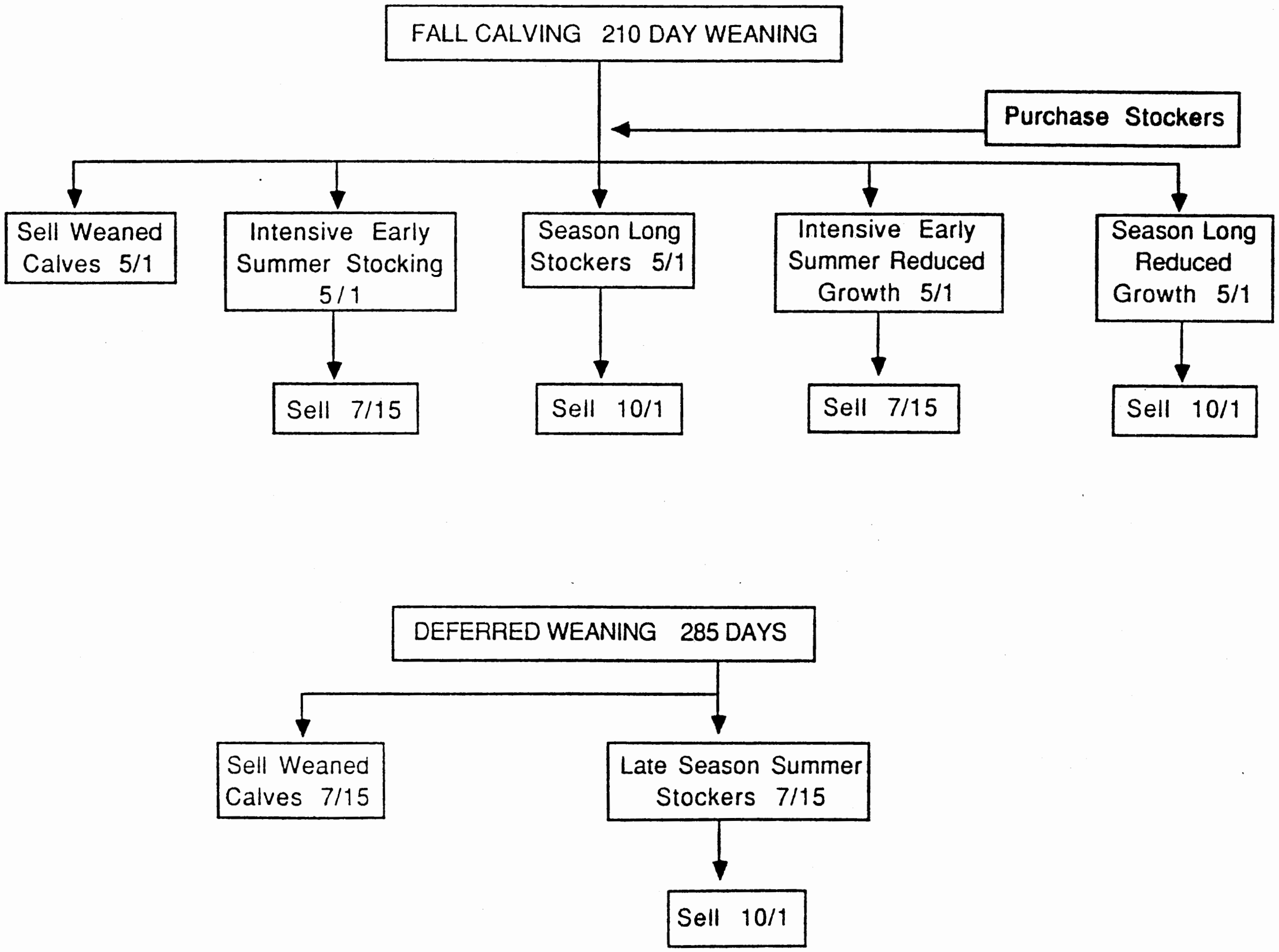

Figure 4. Fall-Calving Flow Chart

TABLE VI

ALTERNATIVE STOCKER PRODUCTION ENTERPRISES

Stocker Activity	Period	Days Held	Starting Weight	Ending Weight	ADG
Fall Pasture Steers	11/1-3/15	135	450	720	2.00
Fall Pasture Heifers	11/1-3/15	135	435	696	1.93
Fall Pasture Low-Gain Steers	11/1-3/15	135	450	664	1.60
Fall Pasture Low-Gain Heifers	11/1-3/15	135	435	643	1.54
Grazeout Steers	3/15-5/15	60	720	840	2.00
Grazeout Heifers	3/15-5/15	60	969	812	1.93
Grazeout Low-Gain Steers	3/15-5/15	60	664	760	1.60
Grazeout Low-Gain Heifers	3/15-5/15	60	643	735	1.54
Winter Supplemented Steers ES	11/1-7/15	255	450	776	1.28
Winter Supplemented Heifers ES	11/1-7/15	255	435	754	1.25
Winter Supplemented Steers SL	11/1-10/1	330	450	901	1.37
Winter Supplemented Heifers SL	11/1-10/1	330	435	875	1.33
Winter Roughed Steers ES	11/1-7/15	255	450	661	0.83

TABLE VI (CONTINUED)

Stocker Activity	Period	Days Held	Starting Weight	Ending Weight	ADG
Winter Roughed Heifers ES	11/1-7/15	255	435	636	0.79
Winter Roughed Steers SL	11/1-10/1	330	450	786	1.02
Winter Roughed Heifers SL	11/1-10/1	330	435	757	0.98
Summer Stocker Steers ES	5/1-7/15	75	400	566	2.21
Summer Stocker Heifers ES	5/1-7/15	75	387	538	2.01
Summer Stocker Steers SL	5/1-10/1	150	400	641	1.61
Summer Stocker Heifers SL	5/1-10/1	150	387	613	1.51
Summer Stocker Steers Low-Gain ES	5/1-7/15	75	400	530	1.72
Summer Stocker Heifers Low-Gain ES	5/1-7/15	75	387	509	1.60
Summer Stocker Steers Low-Gain SL	5/1-10/1	150	400	588	1.26
Summer Stocker Heifers Low-Gain SL	5/1-10/1	150	387	556	1.20
Late Summer Steers	7/15-10/1	75	566	641	1.00
Late Summer Heifers	7/15-10/1	75	543	613	0.93

gain, beginning and ending weights, and days held). The rates of gain used for the various cattle activities were obtained from a variety of sources, including enterprise budgets provided in Walker et al. and Bernardo and McCollum, as well as through communication with researchers in the Oklahoma State University Animal Science Department. The season-long averages obtained from these sources were adjusted to reflect within season rate of gain variation due to intraseasonal forage quality changes.

Beginning with the spring calving season, calves born at 70 pounds are weaned November 1 at an average age of 210 days. Steers weigh an average of 450 pounds (1.81 ADG) and heifers average 435 pounds (1.74 ADG). At this point the calves can either be sold as weaner steers and heifers or placed in one of three stocker options. Stocker cattle can also be purchased for placement in any of the stocker cattle options. No transition period and resulting weight loss was assumed for weaned calves retained in one of the stocker enterprises.

One of the alternative stocker options is to place the calves on wheat pasture November 1 where steers will gain two pounds per day and heifers gain 1.93 pounds per day until March 15. On March 15 the stockers can either be sold or retained on the wheat pasture for a wheat grazeout option. Steers will weigh 720 pounds and heifers will weigh 696 pounds on March 15. If it is most economical to leave the calves on the small grain pasture, they will continue to grow at the same rate of gain until May 15. Following the grazeout period, the calves will be sold. On May 15 the steers will average 840 pounds and the heifers will average 812 pounds.

A second alternative use of fall pasture is to graze the animals at a heavier than normal rate, thus allowing for a reduced growth potential of that assumed above. This strategy will require the producer to employ a limit grazing scheme where forage intake can be limited below the animals normal consumption level. It was assumed that animals would grow at a rate of eighty percent of their unrestricted counterparts. Due to the reduced daily gain assumptions, less forage will be required per animal; thus, pastures may be stocked at heavier rates than are possible with the unrestricted animals described above. If these animals are retained for the grazeout period, they will be transferred at a lower body weight consistent with the assumed average daily gain. They will also continue growing at a reduced daily gain. Average daily gains assumed for this activity, and upon which nutrient requirements were based, were 1.6 and 1.54 pounds for steers and heifers, respectively. These gains result in average weights of 664 pounds for steers and 643 pounds for heifers on March 15. Sell weights on May 15 are 774 and 747 pounds for steers and heifers, respectively.

A second option available for spring born calves is to place them in a drylot where they are fed a low energy diet providing the nutrient level necessary for an average daily gain of 0.75 pounds. On May 1 these stockers are placed on summer pasture where their average daily gain will increase to 2.53 pounds for steers and 2.45 pounds for heifers. On July 15 the calves will either be sold or continue on the summer pasture. If they are retained on late summer pasture enough protein supplement will be available to maintain an ADG of 1.67 and 1.61 pounds per day for steers and heifers, respectively. On October 1 these stocker steers and heifers will be sold weighing 901 and 875 pounds, respectively.

The summer grazing season has been divided into two periods to represent the change in forage quality and the resulting reduced production potential of cattle maintained exclusively on mature late summer forage. In eastern Oklahoma most summer forages have reached a full state of maturity by mid-July and start to decline rapidly in digestible protein and energy levels. Most animals grazing warm season grasses in late summer require protein supplementation in order for any substantial growth to occur. This phenomenon is even more exaggerated in the case of younger animals.

The third alternative available for spring born stockers is to "rough" them through the winter on a ration that just meets their maintenance requirements but allows for no growth until they are placed on summer pasture May 1. The stockers will partially compensate for this non-growth period by having an increased average daily gain. From May 1 to July 15 steers will average 2.81 pounds per day, while heifers will have an average daily gain of 2.68 pounds. On July 15 the stockers will either be sold or retained on summer pasture. If they are left on the summer pasture, sufficient protein supplement will be available to provide the level of nutrients necessary to maintain an average daily gain of 1.67 and 1.61 pounds for the steers and heifers, respectively. The increased rate of gain during the early part of this option is due to "compensatory growth" which is explained in the section under nutritional requirements of cattle.

Production and marketing options included for fall calves are presented in Figure 4, and specific assumptions are listed in Table VI. Calves are weaned on May 1 (210 day weaning), at average weights of 400 pounds for steers (1.57 ADG) and 387 pounds for heifers (1.50 ADG). These calves are placed directly on summer pasture if they are not sold at weaning. On summer pasture they will have an average daily gain of 2.21 and two pounds for steers and heifers until July 15. At this time the calves can either be sold or remain on the summer pasture until October 1. If the calves are kept on summer pasture, the rate of gain from July 15 to October 1 will be 1 pound for both steers and heifers. Protein supplement will be available if required to maintain the specified rate of gain through September. Calves that are kept on summer pasture will be sold on October 1. Average weights will be 641 and 613 pounds for steers and heifers, respectively.

Research in Kansas and Oklahoma has demonstrated that cattle can be grazed at twice the normal stocking density if the grazing period is limited to the first half of the normal grazing season (Bernardo et al.; Smith and Owensby; Launchbaugh and Owensby). This system, referred to as intensive-early stocking (IES) has been shown to give cattlemen greater flexibility in their grazing program. This alternative is feasible due to the fact that the greatest portion of the total dry matter production occurs during the first half of the typical season-long stocker season. Under the season-long stocker activity, forage not consumed is deferred until the latter part of the summer. With the intensive-early stocking activity, no late season forage is required. Since available forage is consumed only in the first half of the season, heavier stocking rates are feasible. Also, several species are consumed that otherwise would be passed by in favor of more desirable forage types. This allows for more thorough use of the forage supply and provides a greater quantity of dry matter that is actually available and consumed by livestock. By dividing the summer grazing season into two periods, intensive-early stocking may be compared to season-long stocking to analyze differences in financial and risk outcomes.

A second alternative for fall born calves is to place them on summer pasture at a heavier than normal rate, resulting in a reduced growth potential. As in the case of fall pasture stockers, it was assumed that the animals would grow at a rate of eighty percent of their unrestricted counterparts. Due to the reduced daily gain assumptions, less forage will be required per animal, and potential exists for employing heavier stocking densities. If these animals are retained through the late-summer period (July 15-October 1), they are transferred with a lower body weight consistent with the reduced daily gain. They will also grow at the same reduced rate during the late-summer season. Average daily gains assumed for this activity, and upon which nutrient requirements were based, were 1.72 and 1.6 pounds for steers and heifers, respectively, during the early summer season. During the late-summer season, expected daily gains are 0.8 pounds for both steers and heifers. These gains result in steers and heifers weighing 530 and 509 pounds on July 15, and 588 and 556 pounds on October 1.

A final option available for the fall calving herd is to delay weaning until the calves are 285 days old. Under this management plan, steers are weaned on July 15 weighing 566 pounds and heifers, 543 pounds. When the calves are weaned, they are either sold or placed on late-summer pasture. Both steers and heifers will receive sufficient nutrition to insure an average daily gain of one pound. If the calves are retained on pasture, they will be sold October 1, at weights of 641 pounds and 613 pounds for steers and heifers, respectively.

Nutrient Requirements of Cattle

Energy and protein requirements are the nutrient factors of primary importance in beef cattle nutrition (Cullison). A deficiency of energy, due to an insufficient quantity of feed of the required quality level, is the most common deficiency in cattle rations. Such a condition may result from overstocking of pastures and ranges, especially in periods of extended drought. With low energy intake, slow or even negative growth rates, late recycling, poor conception rates and higher levels of morbidity and mortality will result. An energy deficiency is usually accompanied by deficiencies in all other nutrients, particularly protein.

Energy deficiencies can also occur when pasture is mature or hay is of low quality. This is due to the fact that as the quality of the forages decreases, digestibility decreases and the intake capacity of the animal is restricted. Thus, it is possible for an animal to eat forage to stomach capacity yet still not satisfy his energy or protein requirements. Intake restrictions due to forage quality and the animals digestive capacity were factored into this study to account for these effects.

Energy

National Research Council (NRC) tables, from which the nutrient values for this study are derived, use the net energy system as the basis of their formulation. Two advantages of the net energy system for nutrient specification are: a) animal requirements stated as net energy are independent of the diet, and b) feed requirements for maintenance and production functions are estimated seperately (National Research Council, 1984). Net energy required for maintenance is termed NE_m, and net energy available for production is titled NE_g (Lofgreen and Garrett; National Research Council, 1981).

The energy requirements for animals can be described as that level of energy which when supplied will result in no loss or gain in body energy. For some animals near maturity (i.e., adult bulls), maintenance may be the desired feeding goal. For most other animals NE_m is more of a theoretical value used to separate production requirements from that level of nutrition that is necessary for the animal to remain in a given, constant condition.

Maintenance requirements of beef cattle (mcals/day) have been estimated as (Lofgreen and Garrett; Garrett,1980):

$$NE_m = 0.077 * W^{.75}$$

where,

W is the body weight in kilograms

The requirements estimated by this equation are most applicable to animals that are penned in nonstressful environments with minimal activity. Adjustments are necessary for other conditions as well as for sex, breed, and physiological age differences (Garrett, 1971; Webster; Geay). The magnitude of the effects varies from 3 to 14 percent. In general, breeds which mature at heavier weights may require more energy and *Bos indicus* breeds and crosses may require less energy for maintenance than would be estimated by the equation.

The net energy requirements for growth are estimated as the amount of energy deposited as protein or fat. In earlier NRC publications these values have been calculated on an empty body weight gain (EBG) basis. Do to the difficulty of determining empty body weight under practical conditions, this equation was modified in the 1984 edition to estimate requirements on a live weight basis. Live weight is defined as the weight of an animal after an overnight feed and water shrink (National Research Council, 1984). The equation to calculate net energy for growth for steers on a liveweight basis is:

$$NE_g = 0.0557W^{.75}\,(LWG)^{1.097}$$

where,

LWG is the live weight gain anticipated.

Adjustments to this equation are made in the NRC publication to account for the requirements of heifers, different frame sizes and physiological age differences.

Energy requirements for the gestating and lactating cow are based on studies conducted by Ferrell, Garrett, Hinman and Grichting, and reported in the NRC publication. The relationship used to estimate the pregnancy requirements are based on the expected birth weight of the calf and the day of gestation. The energy requirements for milk production have been estimated from the information available for the dairy cow (National Research Council, 1978). The requirements for both gestation and lactation respectively are:

$$NE_m = CBW(.0149-.0000407t)e^{.05883t-.0000804\ t^2}$$

$$NE_m\ (Mcal/Kg\ of\ milk) = .1(percent\ fat) + .35$$

where,

CBW is the calf's expected birth weight.

t is the day of gestation.

The total energy requirement of the cow, determined by adding the maintenance and production requirements, should be adequate to prevent weight loss in most producing cows. Seasonal weight loss may occur during calving and early lactation, and weight gain may occur during late lactation and the nonlactating period. These fluctuations should be minimized to accomplish maximum calving percentages.

The NRC publication also lists the net energy values converted to a metabolizable energy basis. Use of the metabolizable energy system simplifies the calculation of nutrient requirements considerably and thus, is the basis from which nutrient requirements for this study are derived. To calculate the metabolizable energy requirements based on the animals weight and anticipated average daily gain a simple linear equation was formulated based on the published NRC values. The fit of these equations measured by the R^2 value was 98 percent. These equations for steers and heifers are:

$$MERS = .019449W + 3.006228AD - 1.4746$$

$$MERH = .018018W + 3.818775ADG - 1.2769$$

where, MERS is the metabolizable energy requirement of steers.

MERH is the metabolizable energy requirement of heifers.

For the purpose of this study a cow unit was used for calculating nutrient requirements. This method was used to account for the needs of herd bulls and replacement heifers simultaneous to brood cow requirements. From Tables V and VI, the herd composition can be determined on a monthly basis for a 100 cow herd.

The requirements on a per cow basis were calculated on a percentage basis. For example, in January for a fall calving schedule, the herd consists of 92 brood cows, 12 replacement heifers, 88 calves, and 4 bulls. The equation for energy and protein requirements of a cow unit are: (1 mature cow * .92) + (1 replacement heifer * .12) + (1 bull * .04) + (1 calf * .88) = one cow unit's requirements. The calve's nutrient requirements were assumed to be supplied by the milk production of the cow until they weigh 250 pounds.

It was also assumed that the cow had reached a mature weight of 1000 pounds at the time of her first calf's birth and that she would maintain that weight through the remainder of her productive life. Thus, it can be assumed that all cows (i.e., two, three and four year olds) have the same requirements for maintenance, fetal development and milk production. A sufficient plane of nutrition was supplied to allow the replacement heifer to reach a weight of 1000 pounds by the time of her first calving at 24 months.

Protein

Protein is an essential nutrient for animal growth, and inadequate levels result in both decreased gains and intake. Thus, the net energy system used in the NRC formulation also monitors the protein requirements of animals.

The data used in this analysis to predict the crude protein requirements of the different beef classes included in the model were also derived from the NRC publication "Nutrient Requirements of Beef Cattle, 1984." As stated earlier, animal weight and anticipated average daily gain were the two independent variables upon which nutrient, in this case protein, requirements were based. Animals with different frame sizes and sexes also have different needs. For this study a medium frame animal was assumed, and a regression equation was calculated for both steers and heifers. Each equation explained 96 percent of the variation in the observations. Alternative equations were calculated for steers and heifers undergoing compensatory growth and are reported in the following section. The equations to predict crude protein requirements under unstressed conditions are:

$$CPRS = .5382 + .000757W + .260714ADG$$

$$CPRH = .0417 + .000766W + .23525ADG$$

where,

CPRS is the crude protein requirement of steers.

CPRH is the crude protein requirement of heifers.

Formulation of the crude protein requirements for brood cows were based on the maintenance requirements of a 1000 pound cow. Adjustments were made to allow for the additional protein requirements of gestation and lactation. Protein needs accelerate as the pregnancy progresses and are increased by 55 grams per day to account for gestation requirements during the last trimester of pregnancy (Prior and Laster). The protein output in milk (in grams per day) is a function of the pounds of milk produced and the protein percentage of the milk. Milk production varies with individual breeds, but generally ranges from 6 to 31 pounds on a daily basis (Lamond et al.; Williams et al.). The protein content averages 3.35 percent. As a result protein requirements per day for the lactating cow are increased by 0.03 pounds per pound of milk produced.

Compensatory Growth

Additional adjustments to the energy and protein requirements stated above were necessary for stockers which are maintained through the winter on a level of nutrition that allows for very minimal growth and is considered to meet animal maintenance requirements alone. Stocker cattle which are "roughed" through the winter continue to develop body frame, and when placed on summer pasture can compensate for the period of retarded growth through above average growth rates.

This compensatory growth has been defined by Wilson and Osbourne as the ability of an animal, previously restricted in growth, to resume growth at a rate greater than normal for animals of the same chronological age. The ability of animals to recover from the retardation sustained during the period of undernutrition has been well documented. Experiments by Nelson and Campbell; Bohman and Torrell; Knox and Oakes; and Jones et al., demonstrated that young cattle wintered on a low plane of nutrition made the highest gains on spring and summer grasses.

The cause of the compensatory growth is not clear. Wilson and Osbourne concluded that an animals intake was directly related to chronological age thus, the increased growth was due to increased intake. The development of the alimentary tract of animals is only slightly retarded by undernutrition, and is related closer to chronological age than to physiological age (Trowbridge et al.; McMeekan; and Wilson). For this reason, restricted animals would be expected to eat more and gain faster than younger animals of the same weight. Research experiments have demonstrated that compensatory growth is due both to increased intake and increased feed efficiency (Osbourne and Wilson; Meyer and Clawson; Horton and Holmes; and Asplund et al.). For this study the NRC values for medium frame stockers with compensatory growth were used. These values reflect both a greater feed intake and feed efficiency than the unrestricted animal has.

Wilson and Osbourne state that the amount of compensatory growth depends on several factors. Among these are the degree and duration of undernutrition, the stage of development of the body at the commencement of undernutrition and the pattern of re-alimentation. The several different factors affecting compensatory growth may partially explain the high variation and lack of consistency in the results of compensatory growth studies. Due to this variation, aggregation of the results is impossible. Taylor et al. demonstrated that carcass gains for re-alimented cattle, restricted during the winter period, were 40 percent greater than the carcass gains of the control group. Winchester and Howe found similar results. Despite the increased summer gains, decreased winter gains resulted in decreased total gains according to Ruby et al. In the model developed for this study, gains were based on 1984 NRC values for large frame and compensatory medium frame stockers. A nutrient balance was calculated by first determining the level of energy and protein available to the particular size calf, given his intake restrictions of the available forage sources. The rate of gain was then set at a feasible level.

Horton and Holmes demonstrated that compensatory growth effects are greater during the early stages of re-alimentation. The rates of gain for this study were developed with this finding in mind. This study used several of the same methods used by Brorsen in developing compensatory growth adjustments. Based on experimental results found, practical considerations and judgements, the compensatory growth adjustments are dependent on:

1. The animals ADG the past 120 days.
2. 1.0 pound was considered average.
3. Fifty percent of increased gain is due to increased intake and 50 percent is due to increased efficiency of energy utilization.
4. There is a gradual decline of compensatory effects from restricted growth over time.

The adjustments to the standard energy and protein requirement equations stated earlier (i.e., sex, breed and physiological age) are equivalent to the adjustments made for larger frame cattle according to the NRC. Using the values published by NRC, a regression equation was calculated to determine the energy and protein requirements of a compensating stocker steer or heifer. Live body weight and expected average daily gain are the independent variables and nutrient requirement level is the dependent variable. These equations are:

$$ERCS = .020102W + 2.892535ADG - 1.8217$$

$$ERCH = .019004W + 3.4851ADG - 1.5033$$

$$PRCS = .5077 + .000822W + .307321ADG$$

$$PRCH = .4925 + .000797W + .26675ADG$$

where,

ERCS are the megacalories of metabolizable energy required for steers undergoing compensatory growth.

ERCH are the megacalories of metabolizable energy required for heifers undergoing compensatory growth.

PRCS are the pounds of crude protein required for steers undergoing compensatory growth.

PRCH are the pounds of crude protein required for heifers undergoing compensatory growth.

For this study, compensatory growth adjustments based on the above information were included for winter roughed and winter supplemented stockers. Steers and heifers in these two activities had an average daily gain of 0 and 0.75 pounds, respectively, for the period extending from November 1 to May 1. Accordingly, the average daily gain for those animals that had been roughed through the winter was increased by thirty percent during the early-summer season from May 1 to July 15. Animals that had been supplemented with a sufficient level of nutrition to allow an average daily gain of 0.75 pounds during the winter had a compensating increase during the early-summer season of twenty percent. It was assumed that all compensating gain adjustments were made during the first seventy-five days on full feed; thus growth levels during the latter half of the grazing season were consistent with typical stocker gains.

Livestock Budgets

Cost of production information for alternative cow-calf and stocker activities was obtained from OSU livestock budgets developed by Walker, Lusby and McMurphy. Modification of the budgets was necessary to correspond to the assumptions underlying the particular activities modeled in this study. Many of the cost items listed in the budgets are determined endogenously by the optimization model, and thus, were not assigned to the specific budgets (e.g., hay, protein supplement, cattle prices, etc.).

The specific budgets used for the alternative livestock activities are contained in Appendix C. The Oklahoma State University Budget Generator was used by Walker, Lusby and McMurphy in the original development of the livestock and pasture budgets. Major sections of the budget are operating inputs and fixed costs (i.e., depreciation, interest on intermediate capital, and taxes and insurance on machinery). Standard machine performance and cost equations are used in the OSU budget generator computer program to calculate machinery hours and costs per head.

Operating Costs

Salt, Minerals, and Vitamins. Salt, minerals and vitamin requirements are met in part by the ration fed to the animal and are not a large portion of total costs. NRC tables were used to determine animal mineral requirements and normal feed and forage contents. Two pounds of a salt and mineral mix per animal unit month were assumed for each cow unit. Three pounds per animal unit month were assumed for stocker enterprises to reflect the needs of young growing animals. Thus, a steer which is .7 AU would use 2.1 pounds of salt and minerals per month (Walker, et al.).

Normal soil and weather conditions were assumed for this study, thus eliminating the need for special and expensive minerals. Common salt and a good phosphorus and calcium source (i.e., dicalcium phosphate, steamed bone meal, limestone, etc.) are sufficient.

Medical Expenses, Vet-Med, and Livestock Supplies. Estimates for vet-med expenses for one cow-calf unit are given in Table VII while Table VIII has

TABLE VII

VET-MED EXPENSES FOR ONE COW-CALF UNIT

Production Period	Treatment	Head	$/HD	Cost/Cow Unit
1. Weaning Time (Cows and Bulls)				
	Lepto-5	0.94	$0.60	$0.56
	Vibrio	0.94	$1.00	$0.94
	Lice	0.94	$0.64	$0.60
	Worming	0.94	$4.00	$3.76
2. Pre- to Post Calving (Replacement Heifers)				
	IRR-BVD Booster	0.12	$0.68	$0.08
	Vibrio	0.12	$1.00	$0.12
	Lice	0.12	$0.64	$0.08
	Worming	0.12	$3.00	$0.36
(Cows and First Calf Heifers)				
	E-Coli-Rotocorona	0.90	$0.09	$0.81
	Vet Calls	0.10	$25.00	$2.50
3. Pre-Breeding/Pre-Weaning (Calves)				
	Blackleg and Malignant Edema	0.90	$0.13	$0.12
	Implant Steers	0.10	$0.30	$0.14
(Herd)				
	Eartags	2.00	$1.00	$2.00
	Anaplasmosis	2.00	$0.60	$1.20
(Replacement Heifers)				
	Bangs Treatment	0.12	$0.64	$0.08
4. Sick Pen (All Year)				
	Pinkeye	0.10	$3.00	$0.30
	Calf Scours	0.10	$5.00	$0.50
	Pneumonia	0.10	$5.00	$0.50
TOTAL				$14.65

Source: Walker, Lusby and McMurphy, 1987.

TABLE VIII

VET-MED EXPENSES FOR STOCKERS

Production Period and Treatment		Cost Per Head $/Hd
Newly-Arrived or Retained Cattle		
Routine Processing of Cattle		
1. Implant		$1.00
2. Eartags for Pests		$1.00
3. Blackleg and Malignant Edema		$0.12
4. IBR, PL-3, BVD		$0.50
5. Lepto Pomona		$0.15
6. Vitamin A and D(for dry range cond)		$0.10
7. Treatment for lice and grubs		$0.30
8. Worming		$1.50
Subtotal		$4.67
Sick Pen Cattle		
"Example Treatments"		
Treatment 1: Oxytetracycline		
Treatment 2: Sulfamethazine boluses		
Treatment 3: Procaine Penicillian G		
Treatment 4: Erythromycin		
Treatment 5: Tylosin		
Treatment 6: Procaine Penicillian G		
Total Sick Pen Cost @ 0.25/hd[a]	$12.00[b] x .25 =	$3.00
Additional Vet-Med Expenses		
Routine Vet Calls(4.4%/hd)	$30.00 x .044 =	<u>$1.33</u>
Total		$9.00

[a]Assumes 25 percent of newly-arrived cattlle get sick

[b]$12.00 per head times portion of cattle treated (Walker, Lusby and McMurphy)

similar estimates for an individual stocker unit. According to Walker, Lusby, and McMurphy these estimates reflect the costs of recommended beef practices and may not necessarily represent the typical practices of Oklahoma livestock producers. They were used here since they are recommended production practices and are consistent with the level of management assumed in the analysis. A cost of $14.65 per cow was included in the cow budgets.

Expected stocker vet-med expenses will most likely differ between purchased and retained cattle. The medical history of purchased stockers is usually not known and cattle often arrive at the farm after considerable stress. The costs assumed in this study were the same for purchased and retained cattle for simplicity. Total vet-med costs per stocker are $9.00 of which $4.67 is used for processing the animal on arrival. Sick pen costs are $12.00 per stocker and it was assumed 25 percent of the animals will be treated. Thus a cost of $3.00 per stocker is included in the budgets. The remaining $1.33 of the $9.00 may be attributed to routine vet calls. A vet call will cost $30.00, and it was assumed 4.4 percent of the calves will require a vet call.

Livestock vet-med and supply costs include use of essential expendable items for vet-med use such as calf-puller, syringes, needles, ear taggers, wormer guns, implant guns, bulling guns, thermometers and other supplies. Equipment such as pliers, hammers and other tools, branding equipment, horse tack, saddle, ropes, refrigerator, clippers, knives and dehorners are also included. Stocker vet-med and supply costs are $2.08 per head per year, while supply costs are $2.78 for each cow unit. Several of these items have many years of useful life, but replacement items are bought each year and represent fairly regular expense items (Walker, et al.).

<u>Hauling Charges</u>. A custom charge of $.35 per cwt. was used for hauling cattle to and from the salebarn. A 50 mile haul at $2.75 per mile with a 393 cwt.

truck pay weight was used to obtain the $.35 per cwt. cost. On-farm hauling costs are reflected in the pickup and stock trailer costs calculated by the budget generator.

Labor. The labor needed for cattle enterprises comes from machinery and equipment operations as well as from feeding, marketing and other animal care requirements. Machinery labor requirements were calculated directly from tractor and truck hours used. Machinery labor requirements were derived from the OSU budget generator and based on machinery performance and use estimates. Total labor for livestock equipment repair and maintenance was specified as an annual requirement for each equipment item. The machinery compliment and fixed cost assumptions listed in Table IX include annual labor assumptions.

Livestock labor estimates presented in OSU budgets and used here were made as accurate and logical as possible without benefit of intensive time and motion studies. Previous studies, existing livestock budgets and ranch interviews were used in arriving at the estimates (Walker, et al.).

Cow herd labor estimates were made for specified herd sizes and then converted to a per cow basis. Those components included in cow herd labor are breeding period labor, dry cow care, calving care, calf care to weaning and local hauling. Stocker labor includes receiving, feeding and care, local hauling and marketing. Those calves that are retained or held over between stocker enterprises may have a lower labor requirement; however, it was assumed that all animals were purchased, thus making labor requirements consistent throughout.

Machinery and Equipment Operating Costs. Table IX contains a machinery and equipment compliment for the representative ranch. Fuel,

TABLE IX

EQUIPMENT COMPLIMENT AND FIXED COSTS FOR MODEL RANCH

Item	Purchase Price	Life	Hour/Year	- - - $ Per Hour of Use - - - Depr	Insur	Tax	Interest	Annual Cost
3/4 T Pickup	$13,500	5	800	$2.15	$0.07	$0.17	$1.32	$2,968.00
Stock Trailer	$3,400	10	50	$5.38	$0.25	$0.68	$4.73	$552.00
Tractor	$27,800	10	600	$3.26	$0.18	$0.46	$3.45	$4,416.00
Disk	$8,900	12	150	$4.26	$0.21	$0.59	$3.88	$1,341.00
Drill	$7,100.00	10	100	$5.84	$0.25	$0.71	$4.81	$1,161.00
Sprayer	$1,775.00	20	50	$1.68	$0.11	$0.35	$2.15	$157.00
Livestock Equip	$9,900	20	1	$495.51	$32.67	$54.45	$626.18	$1,159.00
Feeding Equip	$3,600	10	1	$324.01	$11.88	$19.81	$227.71	$584.00
Horse	$800	10	1	$24.00	$0.00	$0.00	$78.20	$102.20
Fence/Acre[a,b]	$2,500	25	1	$3.19	$0.22	$0.44	$3.41	$7,260.00
Total Base Annual Cost								$19,699.20
Total Cost-Native Scenario[c]								$14,767.20

[a]40 acre square pasture for improved forages.
[b]80 acre square pasture for native pasture.
[c]For native pasture delete drill and disk; lower fence cost $2.43/acre.

lubrication and repairs are calculated by the budget generator program using standardized machinery cost formulas.

Marketing Costs. A marketing cost of $1.72 per hundred weight was used in all budgets and is based on average marketing charges for different cattle at Oklahoma auctions. Marketing costs for purchased cattle were assumed to be included in the purchase price. All livestock purchase and sale transactions in this study were assumed to take place at an auction.

Intermediate Capital Items and Ownership Costs

The second major section of the enterprise budget contains the fixed costs included in the enterprise (i.e., machinery, equipment and livestock ownership costs). Assumptions concerning the purchase price, salvage value and use of each item is given in Table IX. Interest is calculated on intermediate capital items and reported separately from depreciation, taxes and insurance. The OSU budget generator program uses standardized equations and the purchase or list price of the capital item to calculate the fixed costs. For example, at 3.81 hours per cow per year, a pickup is used 1143 hours per year for 300 cows. Assuming that pickups are kept five years and have 400 hours of useful life, an average of 1143/800 = 1.4 pickups are needed per 300 cows. In practice, the rancher would probably keep a newer road pickup and an older pickup for farm use.

Assumptions concerning the cattle investment and fixed cost calculations are given in Table X. No depreciation is included for cows because they are maintained by raising replacements of equal value and the herd composition remains static across years. Differences between bull purchase and selling prices are reflected in annual sale and purchase of one bull per 100 cows. For

TABLE X

COW-CALF FIXED COSTS

ITEM	QUANTITY	VALUE	INTEREST	CST/CW/YR
BROOD COW	1.00	$425.00	$42.50	$42.50
BEEF HEIFER	0.12	$380.00	$38.00	$4.56
BULL	0.03	$1,200.00	$120.00	$3.60
TOTAL				$50.66

Assumes a 10 percent interest rate.
A $50.00 premium over commercial cow cost is included.
A $75.00 premium over market price is included for heifers.

example, in a 100 head cow herd, if one bull weighing 1300 pounds is bought for $100.00 per cwt. ($13.00 per cow) and one bull is sold weighing 1900 pounds for $50.00 per cwt. ($9.50 per cow), then the net bull costs such as feed and medical expenses, are included in operating costs and were apportioned to each cow-calf activity in the model.

Interest on livestock capital is included in fixed costs. Because most of the capital for the bull purchased each year is included in operating capital, interest on only 3.5 bulls per 100 cows is charged in fixed costs. The interest on operating capital in the operating cost section is calculated on net operating debt outstanding each month across the production year. These values per activity were calculated exogenously and then a capital row was included to allocate this expense in accordance with the activities selected by the model. A new production year begins each year after the calves are sold.

In addition to a portion of a bull, each cow unit includes 12 percent of a replacement heifer and one cow. In calculating the heifer's investment value through the production year, her average weight was multiplied by the value of an animal of that class. Since the heifer is selected for her above average traits, a premium value is assumed over the normal market value. A breeding value premium of $75.00 was used as an estimate (Walker et al.). Personal taxes on cattle are included in operating costs, and no insurance is assumed to be purchased for the cattle.

Production and Sales

The third section of the budget contains production amounts and values. A death loss of two percent is imposed on the cow herd (12 cows are replaced annually and only 10 are sold). Also, only 98 percent of the stockers from any of the activities are sold to represent the death loss assumed.

Prices used in the model are an average of the prices received by Oklahoma producers for the past ten years with deviations from the average included in the appropriate net return deviation rows. The prices were adjusted to represent inflation during the time period. The prices of the primary production (i.e., stockers and calves) are endogenous to the model as discussed earlier. The prices of secondary production (i.e., cows and bulls) are not included as separate sell activities in the model, but are used to lower the production cost included in the objective function coefficient of the cow-calf activity. This value is also based on a ten year adjusted average, with deviations from the average included in the net return deviation rows in the model.

Forage Component of the Model

Forage Type and Yield

The information related to the type of forages and the yields recorded were obtained from university research stations within or near the study area. This information is summarized in Appendix A. The forages selected for consideration in the model are the most common forages grown in the study area. They consist of cool season forages such as wheat, rye and fescue as well as warm season grasses including native prairie and bermuda grass. From this selection of alternative forages, the model selects that combination which results in the optimal forage production plan.

The forage data are compiled for six consecutive years (1981-1986), and consists of several clipping observations within each year. From these observations forage dry matter production was estimated in pounds per acre. For those forages which did not have six consecutive years of data, an estimation of the dry matter production for the missing years was formulated. This was accomplished for wheat and rye, which were missing data for 1981 by using data from 1980. Weather conditions, the primary explanatory variable in dry matter production, of the two years were very similar in both total amount of rainfall and distribution of rainfall. In the case of fescue fertilized with 75 pounds of nitrogen, a linear relationship to fescue fertilized with 150 pounds of nitrogen was calculated. All six years of data were available for fescue receiving 150 pounds. Using the equation developed the data for the two missing years of fescue receiving 75 pounds of nitrogen was estimated. In the case of native range the first two years of data for the period modeled were unavailable. A native range forage dry matter prediction model developed by Powell et al. was used to estimate the missing years data. All six years of data were available for bermuda grass.

After dry matter estimates were derived, adjustments were made to allow for the trampling and waste that occurs when pastures are grazed as opposed to the clipping samples. Thirty percent was deducted from all improved forages to allow for that amount of dry matter production that is not available for consumption due to trampling or other waste (Jones). With native pasture a certain percentage of forage is typically left to maintain the quality of the natural vegetation. A general rule of thumb is to leave about 50 percent of the annual growth of vegetation after the grazing season (SCS Soil Survey of Payne County). After allowing for the initial quantity of native grass left, an allowance was also made to adjust for trampling or other waste. It was assumed that 35 percent of the total forage production was available for animal consumption. These values are consistent with the high level of management assumed for this study (Engle, McCollum, personal communication). Forage dry matter production estimates are listed in Appendix A.

Forage Quality

According to research conducted by Whitson et al., forage quality is an important factor in obtaining feasible program solutions. For the dry matter production data gathered and used in this study, no direct quality information was available. Therefore, it was required that typical forage quality estimates be approximated for each of the forages in the different bi-monthly subperiods.

In research done by Brorsen, a similar problem was encountered. Brorsen used Oklahoma data compiled from research by Smith; Wilson; Mader; Powell et al., and Wagner to estimate forage quality levels. The NRC publication "Nutrient Requirements of Beef Cattle" and experiments conducted by Bryan et al., Reid and Jung, and a summary of experiments from the Southern Regional Research Projects S-45 were also used as a basis for values reported in Brorsen. Nutritional values used in this study were based on the research referenced above and upon personal communication with OSU Agronomy and Animal Science researchers.

The quality estimates used for native range in the alternative subperiods were taken from research conducted by Waller, Morrison, and Nelson. Their study recorded native forage quality for central Oklahoma from 1947 to 1962 and was assumed to be a good representation of a "typical" native range site. Due to the wide variety in native range sites and their respective forage conditions a typical site is difficult to define.

Brorsen and Waller et al. recorded TDN and crude protein values for a variety of forages. For this study, TDN was converted to metabolizable energy by the relationship, 1 pound of TDN = 1.64 megacalories of metabolizable energy (Schnieder and Flatt; National Research Council, 1976; Agricultural Research Council). Crude protein values reported in the previously mentioned studies were employed in this study.

Quality coefficients for the respective forages are included in Table XI. The values reflect the seasonal pattern of forage nutrition variation. New growth of forage is the highest in quality; as the plant matures and lignin percentage increases, quality drops. For forages that are past full maturity, weathering also deteriorates forage quality gradually.

Forage quality coefficients were used in determining the intake capacity of alternative livestock classes for each of the individual forages during the six subperiods. As explained previously, intake capacity is a function of both the animals age and also the quality of the feed being consumed. After the intake constraints were calculated, the quantities of crude protein and metabolizible energy supplied by the ingested feed were determined for each livestock class. Each of these coefficients were then included in the model, and the model endogenously determined the optimal forage production plan and the allocation of the forage produced to the alternative livestock activities.

A common practice in the study area is to defer native production for fall or winter consumption. Thus, the deferment of forages for later consumption was included for all forages with the exception of small grains. Quantity as well as quality adjustments were made to represent the deterioration of forage which is not harvested prior to maturity. Dry matter losses occur due to several factors including weathering and rodent and insect damage. In the case of small grains, forage can be deferred for later consumption during the fall and spring growth periods, but forage can not be deferred for summer consumption. Also, no carryover into the next growing season or reverse flow of forage production was allowed for any forage type.

TABLE XI

PASTURE AND FEED QUALITY VALUES

Pasture	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wheat												
TDN%	71	75	77	75	70	60	0	0	0	0	75	69
CP%	17	20	22	17	15	8	0	0	0	0	22	17
RYE												
TDN%	71	75	77	75	70	60	0	0	0	0	75	69
CP%	17	20	22	17	15	8	0	0	0	0	22	17
Fescue												
TDN%	58	57	64	67	60	57	0	0	0	0	64	59
CP%	6	5	10	14	10	7	0	0	0	0	9	7
Native												
TDN%	43	43	42	50	68	64	60	57	58	52	45	44
CP%	2	2	2	4	9	7	5	4	4	3	2	2
Bermuda												
TDN%	0	0	0	0	67	60	58	57	58	53	0	0
CP%	0	0	0	0	14	11	7	7	8	6	0	0
Bermuda Hay												
TDN%	49	49	49	49	49	49	49	49	49	49	49	49
CP%	6	6	6	6	6	6	6	6	6	6	6	6
Protein Supl.												
TDN%	78	78	78	78	78	78	78	78	78	78	78	78
CP%	38	38	38	38	38	38	38	38	38	38	38	38

Adapted from Brorsen, 1980; Waller and Waller, 1972.

Annual Forage Yield Deviation

Variability in the forage yields for each alternative forage is measured as the absolute deviation from the mean production for that subperiod. The annual deviations are simply the difference between the actual dry matter production for that period and the six year mean for the forage in the same subperiod. This deviation set represents the excess or shortage in forage supply during the six years for which data were gathered and is entered in the risk portion of the model.

To allocate a monetary value to these deviations which are expressed in terms of megacalories of metabolizable energy per acre, hay purchasing and selling activities are included. Hay is sold (purchased) when forage supply exceeds (is below) the mean value for that subperiod. To accurately account for the value of the deviations among the different quality forages, deviations are converted from dry matter production to deviations in the level of nutrients supplied. Energy is the standard that is used to measure the value of the alternative forage deviations.

Average prices paid by farmers for hay in Oklahoma for the six years considered (1981-1986) were obtained and, after adjustment for inflation, used to value the forage deviations. When hay is sold, the estimated cost of production ($25.00 per ton) is deducted from the value of positive or excess hay deviations (OSU Enterprise Budgets). With each of the six years of production there is an equal probability of a positive (negative) deviation occurring. Thus, the expected annual return (expense) from each deviation is equal to its net price divided by six, this value enters the objective function of the model. Subsequently, 83 percent (5/6) of the expected return (expense) from a megacalorie is entered in the risk row of the same year, 167 percent (1/6) of the return (cost), with the opposite sign is included in each of the remaining five risk rows to balance the total deviations. The example in Table XII demonstrates the method used.

Assuming that one ton of hay is available from excess forage production in year one period one in the example, the expected annual return from that ton is equal to its price (p = \$62.22) divided by the number of data years (t = 6). That value (\$10.37) enters the objective row. The remainder of the return (\$51.86) accrues in the actual sale year (risk year 1). This leaves a negative deviation in the other five years equal in magnitude but opposite in sign to the expected annual return. Consequently, -p/t (or -\$10.37) is entered in the risk row of all other years for that subperiod. The positive (or negative) sum of all gross return deviations from forage yield is transferred into the risk constraint row.

Forage Budgets

The information used in developing the forage budgets for the six alternative forage types was gathered from OSU forage budgets. These budgets were modified to fit specific management decisions used for the forage data obtained. All forage data were obtained from research station test plots; thus; the budgets reflect the management practices (i.e., fertilization rates, and planting and harvesting dates) employed by research station agronomists for the individual forage types. The levels of fertilization may be somewhat higher than would be expected under typical management strategies. However, due to the fairly wide range under which a near-linear response of forage production to increased nitrogen can be expected, the levels are not infeasible under the high level of management assumed in this study. Two alternative nitrogen fertilization schemes were available for fescue production and were included to analyze the profitability of different fertilization decisions.

TABLE XII

FORAGE DEVIATION PRICING SYSTEM

	Hay Purchase					
	Year 1 Jan-Feb	Year 2 Jan-Feb	Year 3 Jan-Feb	Year 4 Jan-Feb	Year 5 Jan-Feb	Year 6 Jan-Feb
Objective Row	-10.37	-10.37	-10.37	-10.37	-10.37	-10.37
Risk Year 1	-51.86	10.37	10.37	10.37	10.37	10.37
Risk Year 2	10.37	-51.86	10.37	10.37	10.37	10.37
Risk Year 3	10.37	10.37	-51.86	10.37	10.37	10.37
Risk Year 4	10.37	10.37	10.37	-51.86	10.37	10.37
Risk Year 5	10.37	10.37	10.37	10.37	-51.86	10.37
Risk Year 6	10.37	10.37	10.37	10.37	10.37	-51.86

Variable costs associated with pasture management and small grain production were taken from Walker, Lusby and McMurphy. Some modification was necessary to correspond with the assumptions made in this study. In the case of fescue and bermuda grass, which require an establishment cost, the cost was prorated equally over a ten year period. Fertilizer prices for the six year period modeled were obtained and indexed to 1986. Deviations from the mean nitrogen, phosphorus and potassium prices were summed and then included in the appropriate risk rows. Fertilizer price movements were the only source of risk explicitly included in the forage production activities. Specific forage budgets are listed in Appendix B.

Finally, the total amount of land assumed was 1000 acres which is above the average for the eastern Oklahoma region. The land base assumed for the model was divided into two categories: a) acreage which could be used for annual forages or improved pastures and, b) acreage which could be used for native pasture production or improved pasture. This assumption was made to represent that portion of a ranch located in eastern Oklahoma which would typically be too steep, rough or otherwise excluded, from the production of small grains. Of the 1000 acre base, 600 acres were allocated to native prairie or improved pasture production, and the remaining 400 acres were available for the production of improved pasture or small grains.

CHAPTER V

RESULTS AND ANALYSIS

This analysis was conducted under the assumption that producers make their production plans with expectations that average livestock prices and forage yields will prevail. The model was developed to derive efficient long-run E-A forage and beef production and marketing plans that could feasibly reduce the adverse effects of uncertain beef prices and forage yields. Alternate scenarios to the base were developed and analyzed to compare the effect of critical adjustments to the base assumptions and to evaluate alternative management scenarios.

In the base model, the assumption was made that forage not consumed during a specific subperiod could be transferred into subsequent subperiods for consumption. All forage transferred into a later subperiod was done so at a lower quality due to increased maturity consistent with forage quality coefficients of the subsequent subperiods. In the first alternate model developed, the forage transfer was deleted to analyze the risk-return cost of exclusion of the potential to defer forage for later consumption. All other assumptions were identical to the base.

In the second alternate model analyzed, the fall calving-deferred weaning option was eliminated. In the base model this activity is the most prevalent cow-calf activity in the farm plans. Fall calving-deferred weaning was eliminated from this model to analyze the effect on risk-return relationships and to determine the point and magnitude at which the next most favorable cow-calf activity would enter the farm plan. All other assumptions were consistent with those made in the base model.

The third scenario was identical to the base, with the exception of the production coefficients assumed. The reproductive and growth coefficients assumed in the base model are consistent with NRC values as well as being supported by Oklahoma State University research reports. However, due to various factors, several producers actually operate on a lower production frontier than that assumed. Thus, this model was developed to consider the consistency of the livestock-forage trends under a less efficient level of production response.

The final alternate model involved the elimination of all improved forage sources. Several producers in the study area are constrained to the use of native range exclusively, due to soil or topography restrictions. This model was developed to analyze the changes in organization of the alternate ranch plans when there is no opportunity to economically produce any source of improved forage. All other assumptions were consistent with the base.

Results of the different scenarios are presented and comparisons are made between the alternate models and the base. Also, more detailed discussion of the different models is presented as the individual results are discussed. In addition to the E-A frontier for each of the alternate scenarios, ranch organizations corresponding to the alternate points on the E-A frontier are presented and organizational trends under the alternate parameters are analyzed.

Base Model Scenario

The base model was developed for a representative eastern Oklahoma farm with a land base consisting of 1000 acres, of which 600 can be used in the production of either improved or native pasture. The remaining 400 acres are available for either improved pasture or small grain production. All of the livestock and forage activities previously discussed in Chapter IV are potential production activities for this scenario.

The E-A frontier derived for this scenario is presented in Figure 5. The alternate ranch organizations corresponding to each of the points on the E-A frontier are summarized in Table XIII. Returns for all scenarios are stated as returns to land and management. The risk measure associated with each of the respective expected net incomes is stated in terms of the total negative deviations from the expected income level. Alternative risk-efficient production plans are presented for incremental reductions of $10,000 in total negative deviations.

The first point on the E-A curve (point A), which is also the linear programming solution, or the profit maximum, results in an expected net return of $68,555 with an associated total negative deviation of $48,735. This profit maximizing organization for the representative ranch is the most risky production plan derived and involves the production of two stocker enterprises on a combination of bermuda grass, fescue, rye, and native pasture. The stocker enterprises employed, winter pasture stockers and summer stockers, constitute two of the more risky production alternatives available in the model. Historically, income from fall stockers has been unstable due to unreliable winter pasture production and relatively large fluctuations in cattle prices during the period of production.

Analysis of Table XIII illustrates the alternative farm plans and the changes that occur in forage and livestock enterprises as the acceptable level of risk is altered. An analysis of farm plan C is presented to illustrate the information available from the alternate farm plans. Expected income is

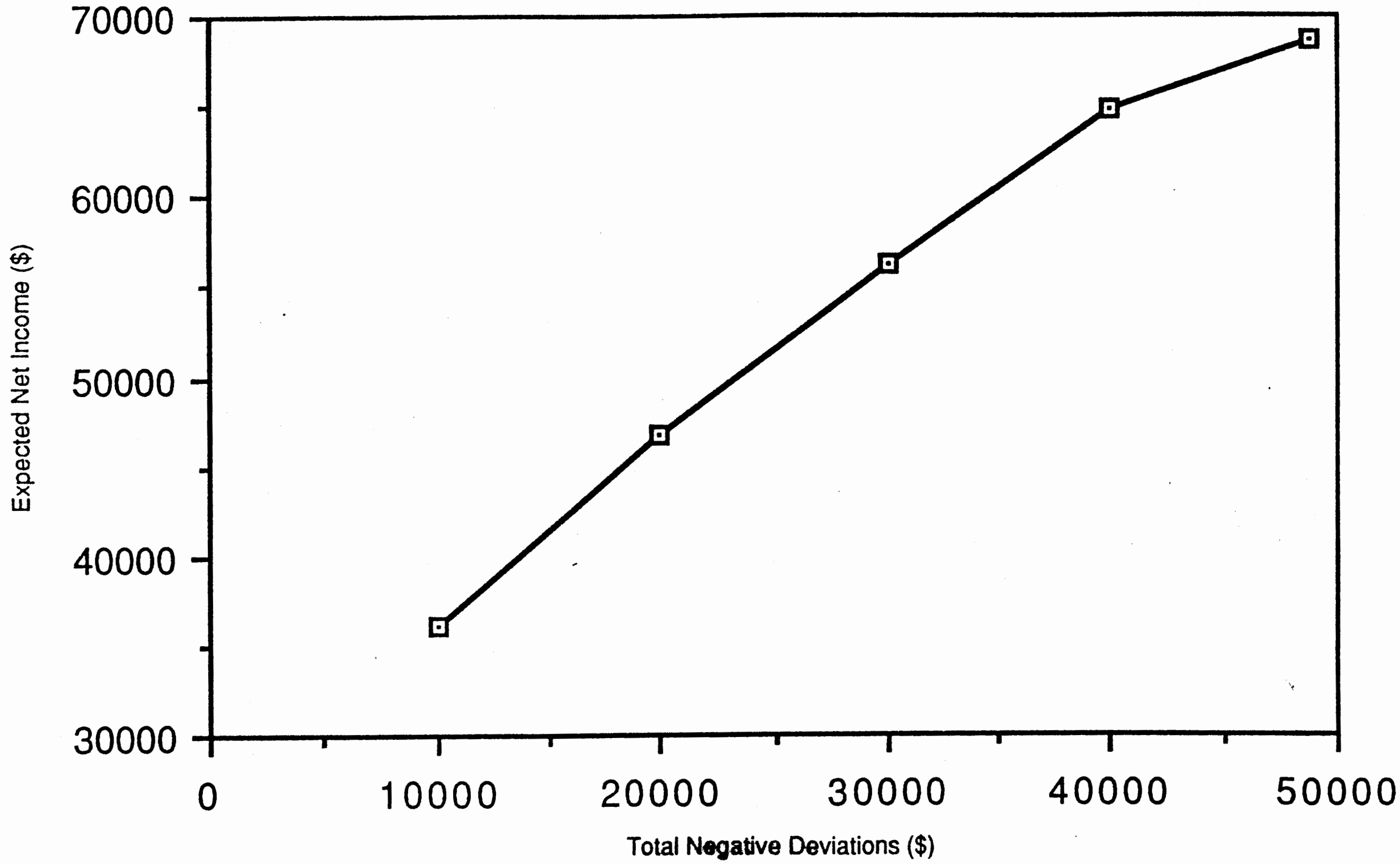

Figure 5. E-A Efficient Farm Organization: Base Scenario

TABLE XIII

E-A EFFICIENT FARM ORGANIZATION: BASE SCENARIO

	Farm Plan				
	A	B	C	D	E
Total Negative Deviations ($)	48,735	40,000	30,000	20,000	10,000
Expected Net Returns ($)	68,555	64,793	56,312	46,834	36,042
Livestock Activities (head)[1]:					
Summer Stocker Heifers SL	406 (a,d,e)	155 (a,d,e)			
Grazeout Low-Gain Heifers	1,484 (a,c,e,f)	1,262 (a,c,e)	957 (a,b,c,e)	571 (a,b,c,e)	151 (a,b,c,e)
Retained Late Summer Steers		8 (d)	48 (d)	79 (d)	84 (d)
Retained Late Summer Heifers		6 (d)	35 (d)	57 (d)	61 (d)
Retained Fall Pasture Steers					32 (a,c,e)
Retained Winter Roughed Heifers SL					23 (c,d,e,h)
Fall Cow-Calf 285 Day Wean		19 (a,c,d)	109 (a,b,c,d,e)	179 (a,b,c,d,e)	192 (a,b,c,d,e)
Spring Cow-Calf 210 Day Wean					74 (a,c,d,e)
Pasture & Feed Activities:					
(a) Rye (A)	400	400	297	159	33
(b) Grain Wheat (A)			103	241	367
(c) Fescue (A)	282	206	232	230	186
(d) Bermuda (A)	134	24	35	58	95
(e) Native (A)	184	370	333	312	319
(f) Ranch Produced Hay (T)	406				
(h) Protein Supplement (T)					1.2

[1]Feeds utilized by each livestock enterprise are reported in parenthesis and correspond to the letters noted in the pasture and feed section.

$56,312 with an associated risk level of $30,000. In this plan, 957 low-gain heifers are pastured from November 1 through the grazeout date, May 15. The prevalent forage source consumed by this group of animals is rye; other sources of feed are fescue, native pasture, and wheat in descending order of the amount consumed. Feed sources are represented by the small case letters in parentheses directly under the livestock numbers listed in the alternate farm plans. Each of the small case letters corresponds with one of the pasture or feed activities listed at the bottom of the table.

The fall-calving deferred weaning herd is a prevalent part of the livestock production plan. Cows serve as a source of forage "clean-up" as illustrated by their diversified diet. Each of the alternative forages produced make up a part of the brood cows diet. Wheat and rye forages, which are high in digestible nutrients, serve as a source of nutritional supplement to offset the nutritional deficiencies of the forages which are consumed after their peak quality has passed (e.g., native pasture consumed during the winter). Due to the model's ability to allocate the required combination of forages to meet livestock nutrient constraints, no protein supplement is required. Typically, high levels of protein supplement are required when a fall calving scheme is employed; however, a portion of the protein requirement can be met through the production of high quality forages, such as small grains, when their production is feasible. Calves from the cow-herd are weaned July 15 at 285 days. Steers weigh 566 pounds while heifers average 543 pounds. After weaning, calves are retained on bermuda grass, which is of sufficient quality to insure one pound of gain for the steers and 0.93 pounds of gain for the heifers per day until they are sold October 1.

Production activities which are common to each of the farm plans on the E-A boundary are production and selling of low-gain fall pasture heifers and rye, fescue, native and bermuda pasture production. Farm plans A and B also include season-long heifers on summer pasture and plan A includes the production of 406 tons of bermuda hay. Plans B through E include a fall cow-calf activity with the calves being weaned at 285 days and then retained on late summer pasture until October 1. Plan E, the most conservative plan with expected net returns of $36,042 and annual negative deviations of $10,000, includes a spring calving enterprise with the weaned steers being retained on fall pasture and the heifers being roughed through the winter before going to season-long summer pasture.

The optimal stocking rates determined by this analysis are somewhat heavier than are normally practiced in the study area. The above average stocking densities are due to three principle factors. First, the use of heavier than normal fertilization rates in generating the forage production data result in high production levels of improved pasture. Second, forage yields for the native pasture were estimated from a relatively high producing range site in the study area. A third cause of the heavy stocking rates concerns the ability of the model to allocate forage dry matter production at the optimal level. The model is constrained to meet nutrient requirements of different livestock classes subject to dry matter intake restrictions. Once the animals nutrient requirements are met, the model may allocate all additional forage to additional animals. If a producer had the ability to determine the exact nutrient requirements of his animals, the nutrient level of the ingested feed sources, and the dry matter production per year, he could stock his pasture so as to allow only that level of intake that would meet nutrient requirements and leave no forage in excess of that demand. In practical situations, however, this level of management is probably not attainable.

Movement downward along the E-A frontier shows a general increase in the production of wheat harvested as grain and cow-calf numbers. These increases are associated with decreases in the production of rye and purchased stocker activities. As risk is reduced, the slope of the E-A frontier steadily increases. Thus, initially as the producer forgoes income, risk can be reduced 2.6 times as rapidly. This relationship declines however, to the point where in order to attain the final risk-conservative plan (plan E), $1.08 of expected net income must be forgone in order to reduce negative deviations $1.00.

As the degree of risk aversion increases, two significant changes in the livestock plan are observed. First, total livestock numbers are decreased reducing forage demand and, hence, decreasing pasture utilization and supplemental feed requirements. Forage demand decreases at a decreasing rate between each of the farm plans. Thus, the profit maximizing scheme includes stocking rates consistent with the most favorable forage production years, while the risk averter will plan for low forage production years. Stocking rates will be more consistent with average to below average production conditions as the producer's degree of risk aversion increases.

Second, more income stable livestock enterprises are substituted for riskier production activities. As the level of risk aversion is increased, cow-calf production becomes a more important component of the farm plan. The presence of cow-calf enterprises in the risk efficient plans is consistent with the large number of cow herds found in the study area and is supported by results reported in other studies (e.g., Gebremskel and Schumway). Stocker production is considerably more risky than cow-calf production due to the price variability of purchased stockers. A stocker producer must concern himself with production variability as well as the marginal movement of prices between the purchase and sale of stockers. The level of risk associated with intensive stocking schemes is even greater due to the increase in the number of animals held during the production period. While a cow-calf producer has higher fixed costs, he is faced with only one source of price movement which occurs when calves are sold.

Fall calving with deferred weaning is the first cow-calf activity to enter the farm plan (plan B). Although fall calving is not widely practiced in the study area, researchers have demonstrated the economic feasibility of fall calving, particularly when a deferred weaning scheme is employed (Saez et al.). Season-long summer stockers are eliminated from the ranch portfolio as the fall calving cow herd increases. This elimination is due to the high-quality forage requirements of the cow herd during the early phase of the summer stocker activity. From May 1 to July 15, when calves are weaned, the cow herd has a high quality nutrient requirement. A large portion of the nursing calves actual nutrient supply comes from forage consumption during the last few months prior to weaning. Thus, a retained stocker enterprise is in essence employed and eliminates the more risky purchased stocker activity from the ranch plan. Fall and winter pasture stockers more closely compliment the fall calving herd since the period of their high nutrient requirements does not conflict as dramatically as summer stockers. All calves weaned from the cow-calf herd are retained on summer pasture through October 1. Retained calves are kept on bermuda pasture which is of sufficient quality to allow one pound of gain per day. Typically, calf prices are slightly higher and less variable in October than in mid-July due to the increased demand for fall pasture stockers. These factors explain the retention of weaned calves even though the average daily gain is relatively low.

In the most risk averse plan, spring calving cows replace the majority of the low-gain heifers on fall pasture. Steers from the spring calving herd are grazed on small grain pasture. The heifers are kept on a maintenance diet of deferred native grass and fescue and then placed on summer pasture where they experience increased gains due to compensatory gain. With the diversified forage system available to the producer, it is conceivable that two alternate cow-calf activities would enter the optimal farm plan. Due to the alternate seasonal demand for high quality forage, spring and fall calving herds can compliment each other by more thorough use of the lower quality off-season forage.

As the level of risk is reduced, diversification of both forage and livestock activities increase. This phenomenon occurs under all production assumptions employed in this study and is consistent with economic theory. That is, as diversification increases, the associated level of risk will decrease so long as the activities included in the diversification scheme are not perfectly correlated. This applies in a general sense to both the forage and livestock activities. When conditions are less than favorable for a certain production activity, losses can be minimized with alternate sources of income in the production portfolio.

Regardless of the producers level of risk aversion, a diversified pasture system is included to insure year-round forage supply. However, as the level of risk aversion increases, the forage plan becomes even more diversified as more stable-producing forages are substituted into the plan. Table XIV presents a comparison of the average annual production, average cost of production per ton and the variability of production of each forage. To estimate the variability, the standard deviation was calculated for each of the forage types.

Analysis of this table provides some explanation of the observed trends in pasture acreage. As the allowable level of risk is reduced, wheat harvested

TABLE XIV

FORAGE PRODUCTION COEFFICIENTS

Forage	Cost/Acre	Annual Average Forage Prod. (lbs)	Standard Deviation	Average Cost/ Ton of Forage
Bermuda	$110.00	10,501	2,209	$20.95
Fescue	$44.00	3,721	265	$23.65
Rye	$100.34	5,334	1,415	$37.62
Native Prairie	$2.50	1,977	462	$2.52
Grazeout Wheat	$94.00	3,526	937	$40.03
Grain Wheat	-$38.41	1,303	462	$0.00

Cost of wheat harvested as grain is negative to reflect returns above production costs which are grazeout production costs plus harvesting costs.
Average forage production and deviation are based on average dry matter production through March 15.
For this study, costs are allocated to grain production and thus forage is a free byproduct.

as grain is continually substituted for rye. Although average annual forage production of rye exceeds that of wheat, it has a significantly higher level of risk associated with its production than wheat. Grain yields have levels of variability similar to forage yields; however, the price variability of grain is considerably less than that of beef. Also, the grazeout option has the added risk of the uncertainty of production associated with converting forage to beef. The combination of these two factors together explains the lower risk generally associated with grain production than the grazeout option.

A second trend associated with lower risk preferences concerns the substitution of native range for improved pasture. Bermuda production, is characterized by the highest average dry matter production per year; however, it also is characterized by relatively high production costs and production variability. Initially, bermuda grass is replaced by native range as risk is reduced. Trends observed in bermuda grass acreage are also consistent with the cattle enterprises included in the alternate ranch plans. As summer stockers are replaced by the cow herd, the nutrient requirements of the cow herd can be met by the production of native grass. However, as the number of late season retained stockers increases, the level of bermuda grass once again gradually increases in order to meet their nutrient requirements. Thus, it appears that the variability of livestock production is the dominant source of risk, and forages are altered to meet the changing nutritional needs of the various livestock activities.

The linear programming solution includes the production and feeding of large quantities of supplemental hay. Under this farm plan the producer plans on above average production and uses all forage produced. Excess summer forage is stored as hay to allow for heavier stocking rates during the winter when forage production is more variable. Hay production is eliminated from the ranch plan as risk is reduced due to the costs associated with hay production.

Stocking densities of the fall pasture stockers are reduced, eliminating the need for supplemental hay feeding. Also, to sustain livestock during the winter period, substantial amounts of summer and fall forage are deferred for consumption. While this deferred forage is not high in nutritional quality, it does serve as a filler, and when combined with adequate amounts of higher quality forage serves as a good source of feed supply. Under the conditions of this analysis, a rancher will realize greater economic returns by deferring forage for winter consumption rather than storing large quantities of supplemental hay to be fed during the winter.

Forage Transfer Exclusion Scenario

In the base scenario it was assumed that forage not consumed during a subperiod could be transferred at a lower quality, consistent with increased plant maturity, to a subsequent period. The process of deferring forage for later consumption is a common practice in the study area (McCollum, personal communication). With the exception of Bartlett et al. and Anderson, the previous studies reviewed did not explicitly include this practice in their production models. The objective of this scenario was to determine the effect that overlooking this consideration would have on risk-return tradeoffs.

The E-A frontier for this scenario is presented in Figure 6, and the alternate ranch plans are summarized in Table XV. All assumptions in this scenario are identical to the base model with the exception of the inter-period forage transfer activity being eliminated. Thus, all forage produced in a given period must be consumed during that period or it is wasted. This adjustment lowered the expected net return of the LP solution \$13,473 below the base solution while increasing the total negative deviations by \$34,851. Due to the lower expected net returns at equal negative deviations, the frontier in this

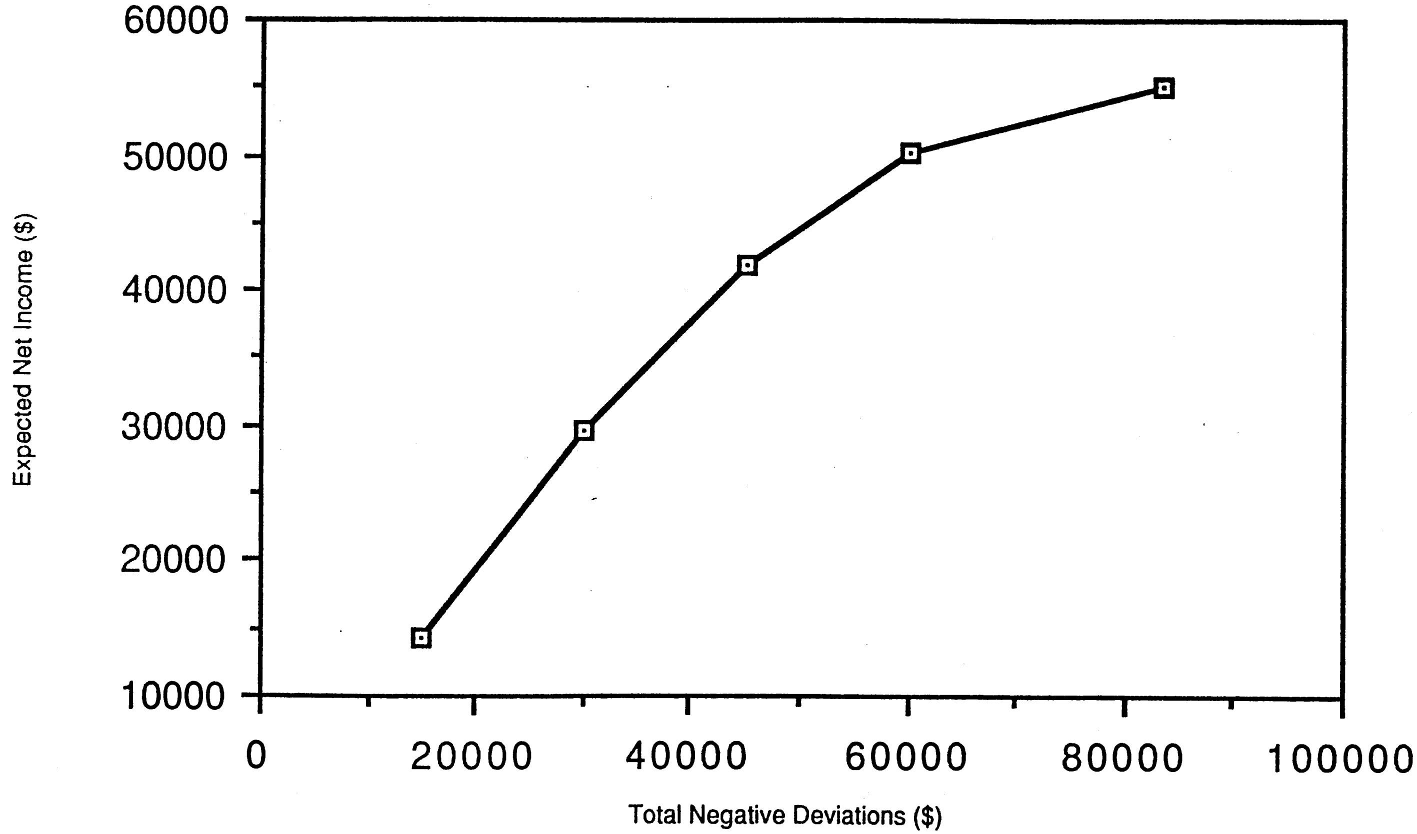

Figure 6. E-A Efficient Farm Organization: Forage Deferral Elimination Scenario

TABLE XV

E-A EFFICIENT FARM ORGANIZATION: FORAGE TRANSFER ELIMINATION SCENARIO

	Farm Plan				
	A	B	C	D	E
Total Negative Deviations ($)	83,586	60,000	45,000	30,000	15,000
Expected Net Returns ($)	55,082	50,222	41,838	29,753	14,232
Livestock Activities (head)[1]:					
Summer Stocker Heifers IES	706 (d,e,g)	26 (d,e,g)			
Fall Pasture Steers	293 (a,g)	293 (a,g)			
Summer Stocker Steers IES	394 (d,e,g)	1,082 (d,e)	281 (d,e)		
Summer Stocker Heifers SL	137 (d,e,g)	172 (d,e,g)	232 (d,e,f,g)	35 (d,e,f,g)	
Grazeout Low-Gain Heifers	821 (a,c,g)	821 (a,c,g)	1,190 (a,c,f,g)	956 (a,b,c,f,g)	426 (a,b,c,f,g)
Winter Roughed Heifers SL				67 (c,d,e,f,g,h)	1 (c,d,e,f,g,h)
285 Day Steer Calves					18
285 Day Heifer Calves					13
Fall Cow-Calf 285 Day Wean					41 (b,d,e,f,g,h)
Pasture & Feed Activities:					
(a) Rye (A)	400	400	400	316	127
(b) Grain Wheat (A)				84	273
(c) Fescue (A)	30	30	118	85	1
(d) Bermuda (A)	30	43	51	32	10
(e) Native (A)	540	527	431	236	108
(f) Ranch Produced Hay(T)			27	39	5
(g) Purchased Hay (T)	255	257	261	205	150
(h) Protein Supplement (T)				3.5	1.9

[1]Feeds utilized by each livestock enterprise are reported in parenthesis and correspond to the letters noted in the pasture and feed section.

scenario is located to the right and below that of the base scenario. The frontier is slightly less steep than the frontier derived in the base scenario.

The profit maximizing plan includes a wider diversity of livestock enterprises than occurs under the base assumptions. Included in the plan are five different stocker activities grazing a combination of five different feed sources. The larger number of livestock production activities probably relates to the seasonal supply of the alternative forages. Small grains, which are the dominant forage source, are limited to 400 acres. The remainder of the land base is allocated among that combination of forages which can supply feed during the alternate seasons of the year and still be within the specified income deviation levels. Since forage may not be transferred among subperiods, livestock enterprises requiring feed at different times of the year are included to utilize available forage.

As in the base scenario, as risk preference is reduced stocking density is reduced, and risky livestock activities are replaced by those with lower income dispersion. Grazeout heifers growing at a reduced average daily gain are the dominant livestock activity under all risk-preference assumptions. Early-season summer stockers are also principal cattle enterprises under low levels of risk aversion, but are eliminated as risk is reduced. The number of season-long summer stockers remains relatively constant under alternative risk assumptions. Early-season stocking is usually considered more risky than season-long stocking. This is due to the increased animal density under IES and, thus, the increased susceptibility to adverse price movements and weather conditions.

Stockers comprise a more significant component of total production under this scenario than under the base assumptions. This is due to the forage requirement of the cow herd throughout the year. In periods of low forage production, this requirement has a high opportunity cost due to the elimination of forage deferral. Another possible explanation of the prevalence of stockers in this scenario is that they are more efficient users of high quality forage. That is, since cows do not require the high level of nutrients contained in young growing plants a portion of that quality is used inefficiently. On the other hand, stockers require a high level of forage quality in order to sustain efficient rates of gain.

The greatest difference between this scenario and the base is the increased marginal value of the supplemental feed sources. Produced hay, purchased hay, and protein supplement are integral parts of the alternate farm plans. Due to the inability to defer forage production to subsequent consumption periods, hay serves as the only means of transferring forage to deficit production periods. A higher level of risk is associated with hay use due to variability in hay price and losses associated with harvesting. Also, it is noteworthy that it is more efficient to purchase hay in this scenario than to produce it. In contrast, hay production was favored in the base scenario over the purchase of hay. Due to the inability to divert forage production to subsequent periods, land has a higher marginal value in the production of forages to meet animal nutrient requirements. Therefore, the marginal value of purchased hay is increased.

Forage trends are less consistent in this case than in the base scenario. This inconsistency is due to the model allocating the land resource to a forage compliment that will provide forage production during all seasons. The replacement of wheat production to be harvested as grain for rye follows the same trend as in the base. Native range decreases constantly as risk is reduced. This is partially due to the higher marginal value of bermuda grass derived from its use in the production of hay. Fescue production is greatly reduced from its level of production in the base, although the trend is roughly consistent. The marginal value of fescue follows the relative importance of the grazeout heifers in both plans since it is used almost exclusively in their production. The marginal value of hay is much higher under this setting as it is the sole source of filling in the periods of deficit forage production. Since it was assumed that bermuda grass is the only grass harvested as hay, the marginal value of bermuda grass production also increases. If hay production from fescue had been an alternative, fescue would have probably remained in the optimal farm plan. Production of native pasture is included in the farm plan at all risk levels due to its extremely low variable production cost relative to the alternate forage sources.

Exclusion of Deferred Weaning Scenario

Cow-calf production is a common practice in the study area as evidenced by the large number of brood cows reported in USDA statistics. The base model indicated that the risk averse producer will include a cow-calf herd in his production portfolio. The earliest entry of cow-calf production into the base model includes a fall calving herd with weaning deferred until mid-July (i.e., 285-day weaning). While this practice is not the most popular cow-calf production option in the study area, some producers do follow such a production plan. Also, research has indicated the economic feasibility of a fall-calving herd with deferred weaning (Saez et al.; Walker et al.). The most widely practiced calving scheme in the study area is a spring calving, 210-day weaning production plan (Neumann). To determine efficient ranch organizations under more traditional calving alternatives, the possibility of deferring weaning of fall calves was eliminated from this scenario. Comparison of this solution with the base will also give some indicator of the dominance of fall calving-deferred weaning over the other calving options employed in this model.

The E-A frontier for this setting is presented in Figure 7 and the corresponding ranch plans are reported in Table XVI. As illustrated in the E-A frontier, very little change in expected net returns occurs when a spring-calving herd replaces the fall-calving option. A spring cow-calf enterprise enters the production plan at the same risk level (total negative deviations equal $40,000) and increases with risk reduction only slightly faster than the fall calving-deferred weaning enterprise in the base. Net income is reduced by a maximum of $1,264 by elimination of the fall calving-deferred weaning herd. The slope of this frontier is slightly steeper than the base, indicating a larger loss in income for incremental reductions in risk.

The LP farm plan is identical to the base solution, and thus, no comparison is needed. The first divergence from the base scenario occurs with plan B, where total negative deviations are $40,000. The expected net returns at this level of risk are $64,713 which is $70 below the expected net returns associated with this level of deviations in the base. As in the base scenario, low-gain grazeout heifers and full-season summer stockers are the optimal livestock activities. This result indicates that while there is very little difference in income-risk relationships between fall or spring calving herds, the fall calving herd is more profitable when the production setting is similar to the one modeled in this study.

Spring calving cows enter the farm plan as risk is reduced and increase in importance as risk is further constrained. As in the base solution, calves are retained after weaning in one of the available stocker options. Steer calves are placed on fall pasture and sold March 15. Wheat pasture has replaced rye consistent with the previously explained risk reduction realized through grain

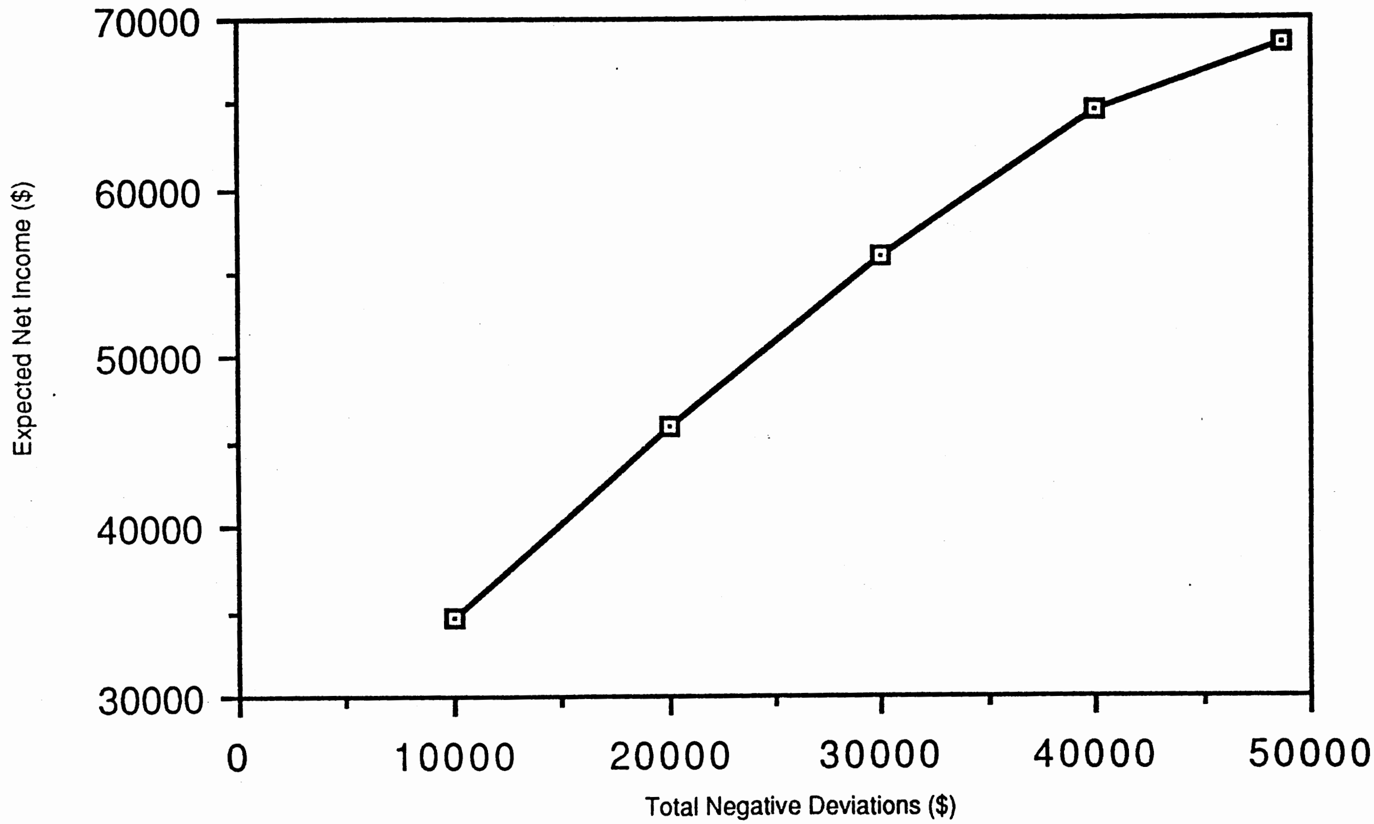

Figure 7. E-A Efficient Farm Organization: Deferred Weaning Elimination Scenario

TABLE XVI

E-A EFFICIENT FARM ORGANIZATION: 285 DAY WEAN ELIMINATION SCENARIO

	Farm Plan				
	A	B	C	D	E
Total Negative Deviations ($)	48,735	40,000	30,000	20,000	10,000
Expected Net Returns ($)	68,555	64,713	55,970	45,973	34,778
Livestock Activities (head)[1]:					
Summer Stocker Heifers SL	406 (a,d,e)	173 (a,d,e)			
Grazeout Low Gain Heifers	1,484 (a,c,e,f)	1,247 (a,b,c,e)	923 (a,b,c,e)	512 (a,b,c,e)	118 (a,b,c,e)
Retained Fall Pasture Steers		9 (a,e)	56 (a,e)	90 (a,e)	110 (a,e)
Retained Winter Roughed Heifers SL		6 (c,d,e,f,h)	41 (c,d,e,h)	66 (c,d,e,h)	80 (c,d,e,h)
Spring Cow-Calf 210 Day Wean		20 (a,c,d,e,f)	130 (a,c,d,e,f)	208 (a,c,d,e)	253 (a,b,d,e)
Pasture & Feed Activities:					
(a) Rye (A)	400	398	315	197	42
(b) Grain Wheat (A)		2	85	203	358
(c) Fescue (A)	282	192	164	110	140
(d) Bermuda (A)	134	30	62	91	95
(e) Native (A)	184	378	374	399	365
(f) Ranch Produced Hay (T)	406	4	23		
(h) Protein Supplement (T)		0.3	2.1	3.3	4

[1]Feeds utilized by each livestock enterprise are reported in parenthesis and correspond to the letters noted in the pasture and feed section.

production. Thus, fall pasture stockers are sold prior to the wheat jointing stage which occurs in mid-March. Heifers, which are retained after weaning, are put in the winter roughing program. During the months from November through May, they are fed a maintenance diet that allows for no weight gain. On May 1 they are placed on high quality summer pasture and experience compensatory gains during the first half of the summer, followed by normal stocker gains during the latter half of the summer. The prevalence of fall and winter pasture stockers is due to the complimentary effect between their forage needs and those of the cow-herd. The spring calving cow herd has a requirement for high quality forage during the summer while fall stockers require quality forage during the fall, winter and early spring. Thus, a strong complimentary relationship exists between fall stockers and spring calving cows.

Forage production trends are similar to production trends in the base. Trends toward summer production are proportionately larger in this case than in the base. More bermuda grass is grown under the alternate farm-plans than in the base, and native pasture increases slightly. This is consistent with the need for high quality summer forage during the season when cows are milking most heavily. As in the base scenario, fescue acreage closely follows the trend of grazeout heifers. As in the base, it appears that cattle enterprise selection drives the model, and forage production is altered to meet cattle nutrient requirements during the alternate production periods.

Protein supplement is included in the two most risk-averse production plans. Supplement is fed at the rate of 100 pounds per head to the winter roughed heifers. The majority of the supplement is fed during the late summer period when forage quality has decreased and a higher plane of nutrition is required to sustain efficient rates of gain.

The use of hay is increased slightly in this scenario due to the slight reduction in fescue and increase in native pasture acreage. During the winter months these two forage sources are the major sources of feed for the cow herd. Due to the replacement of fescue by native pasture, which has a lower average dry matter production, supplemental hay must be increased.

Lower Production Scenario

In the base model, rate of gain assumptions were made to calculate intake and nutrient requirements of the various cattle classes. These assumptions were based upon NRC expectations and data reporting typical Oklahoma cattle production performance parameters (Walker et al.; Bernardo et al.; and Lusby). Gain assumptions employed apply to a herd which has received a high degree of management, and thus, has excellent genetic lines and receives proper nutritional care. NRC requirements are derived from animals which are in an ideal environment with very minimal environmental stress (National Research Council, 1984).

This scenario was developed to analyze the effect of alternative livestock performance assumptions on risk efficient ranch organizations. Due to lower management skills, genetically inferior animals and a host of other factors, the level of production assumed may not be achieved in certain production settings. This model was formulated to analyze adjustments in the results when a lower level of production is expected. Results of the analysis may also be used to estimate the value of improved management.

To analyze the effect of lower production capabilities, it was assumed that the decrease in production efficiency eminated solely from a decrease in beef production. Since the forage data employed represents observed forage response adjusted for trampling and normal animal waste, it is assumed that the forage levels used are levels attainable by eastern Oklahoma producers. Livestock production parameters are somewhat more ambiguous; thus, adjustments were confined to the cattle production assumptions. Stocker average daily gain assumptions were reduced by twenty percent, while weaning percentages and weaning weights were lowered by ten percent, respectively. To realistically portray the effect of lower production, nutrient requirements were maintained at levels necessary for the growth and reproduction assumptions incorporated in the base. Adjustments in the response assumptions may be conceptualized as a downward shift in the response functions relating livestock performance variables (weight gains, weaning weights, and weaning percentage) to ingested levels of protein and energy. Table XVII lists the average daily gain, weaning rate and percentage, and other livestock assumptions employed in this scenario.

The E-A frontier for this scenario is presented in Figure 8, and ranch plans corresponding to the alternate points on the frontier are listed in Table XVIII. All assumptions in this model are identical to the base, with the exception of the previously discussed livestock performance assumptions. The profit maximizing organization results in expected returns of $15,954 with an associated total negative deviation of $22,612. Thus, the alternate livestock performance assumptions translate into a decrease of $52,601 and $26,123 in expected net returns and total negative deviations, respectively. The slope of the E-A frontier is less than the base model frontier, signifying a greater ability to reduce risk for each dollar of expected income foregone.

General livestock trends are consistent with the base model. As risk is reduced, cow-calf production replaces stocker enterprises. As in the base scenario, the first cow-calf activity to enter the farm plan is a fall calving herd (285-day wean), followed by spring calving as risk is further reduced. Cow-calf

TABLE XVII

LOWER PRODUCTION FUNCTION GROWTH ASSUMPTIONS

Stocker Activity	Period	Days Held	Starting Weight	Ending Weight	ADG
Fall Pasture Steers	11/1-3/15	135	450	666	1.60
Fall Pasture Heifers	11/1-3/15	135	435	643	1.54
Fall Pasture Low-Gain Steers	11/1-3/15	135	450	623	1.28
Fall Pasture Low-Gain Heifers	11/1-3/15	135	435	601	1.23
Grazeout Steers	3/15-5/15	60	666	762	1.60
Grazeout Heifers	3/15-5/15	60	643	735	1.54
Grazeout Low-Gain Steers	3/15-5/15	60	623	600	1.28
Grazeout Low-Gain Heifers	3/15-5/15	60	601	675	1.23
Winter Supplemented Steers ES	11/1-7/15	255	450	711	1.02
Winter Supplemented Heifers ES	11/1-7/15	255	435	690	1.00
Winter Supplemented Steers SL	11/1-10/1	330	450	813	1.10
Winter Supplemented Heifers SL	11/1-10/1	330	435	785	1.06
Winter Roughed Steers ES	11/1-7/15	255	450	618	0.66

TABLE XVII (CONTINUED)

Stocker Activity	Period	Days Held	Starting Weight	Ending Weight	ADG
Winter Roughed Heifers ES	11/1-7/15	255	435	596	0.63
Winter Roughed Steers SL	11/1-10/1	330	450	719	0.82
Winter Roughed Heifers SL	11/1-10/1	330	435	694	0.78
Summer Stocker Steers ES	5/1-7/15	75	400	533	1.77
Summer Stocker Heifers ES	5/1-7/15	75	387	508	1.61
Summer Stocker Steers SL	5/1-10/1	150	400	593	1.29
Summer Stocker Heifers SL	5/1-10/1	150	387	568	1.21
Summer Stocker Steers Low-Gain ES	5/1-7/15	75	400	503	1.38
Summer Stocker Heifers Low-Gain ES	5/1-7/15	75	387	483	1.28
Summer Stocker Steers Low-Gain SL	5/1-10/1	150	400	551	1.01
Summer Stocker Heifers Low-Gain SL	5/1-10/1	150	387	531	0.96
Late Summer Steers	7/15-10/1	75	509	569	0.80
Late Summer Heifers	7/15-10/1	75	489	545	0.74

All activities are for purchased obtained stockers.
IES is intensive early stocking.
SL is season-long stocking.

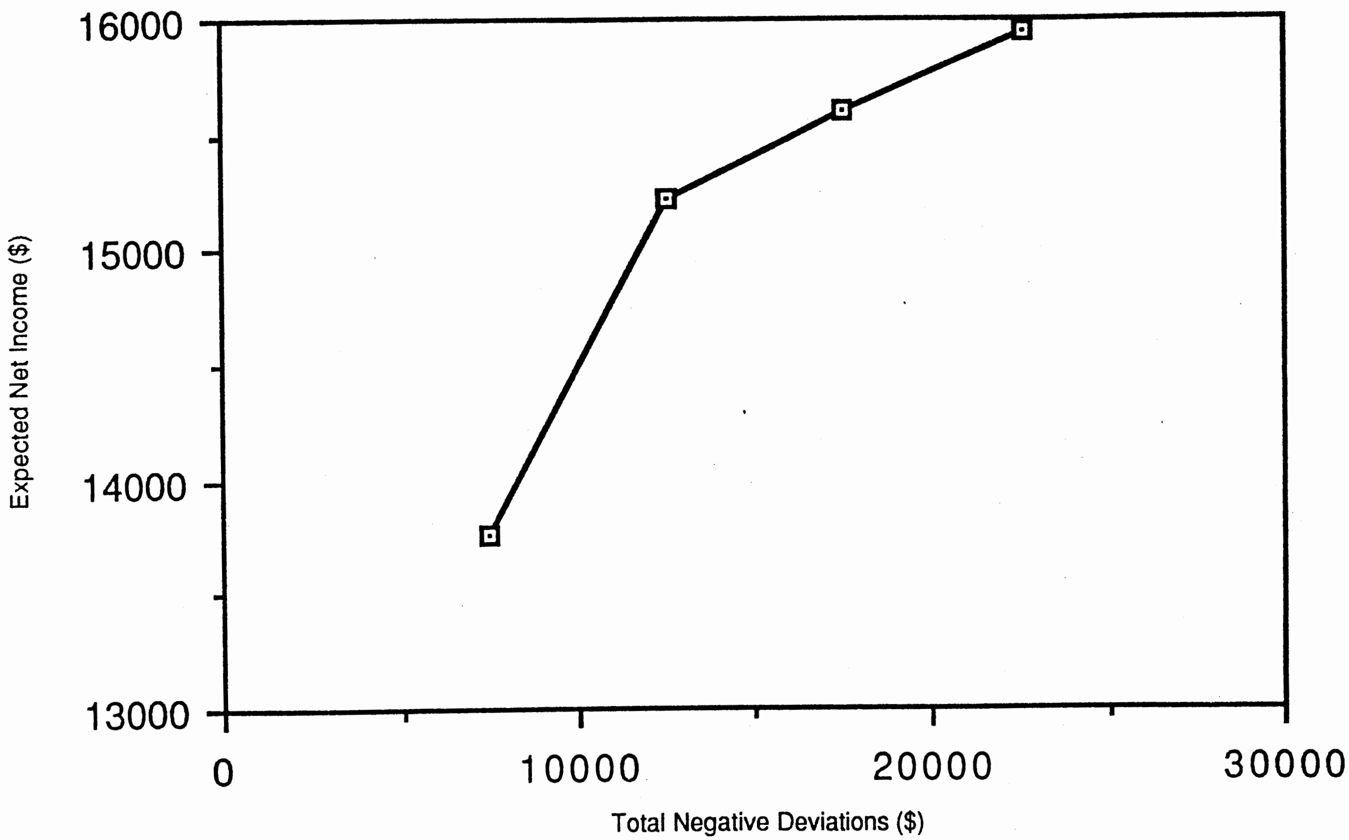

Figure 8. E-A Efficient Farm Organization: Reduced Production Scenario

TABLE XVIII

E-A EFFICIENT FARM ORGANIZATION: REDUCED PRODUCTION SCENARIO

	Farm Plan			
	A	B	C	D
Total Negative Deviations ($)	22,612	17,500	12,500	7,500
Expected Net Returns ($)	15,954	15,605	15,214	13,755
Livestock Activities (head)[1]:				
Summer Stocker Steers SL	444 (a,d,e)	298 (a,d,e)	144 (a,d,e)	
Fall Pasture Steers	335 (a,b,c)	232 (a,b,c)	133 (a,b,c)	16 (b)
Retained Fall Pasture Steers				20 (b)
Retained Winter Roughed Heifers SL				12 (c,d,e,h)
285 Day Steer Calves	37	55	70	44
285 Day Heifer Calves	26	38	49	30
Fall Cow-Calf 285 Day Wean	96 (a,b,c,d,e)	140 (a,b,c,d,e)	187 (b,c,d,e)	176 (b,c,d,e)
Spring Cow-Calf 285 Day Wean				44 (b,c,d,e)
Pasture & Feed Activities:				
(a) Rye (A)	111	62	16	
(b) Grain Wheat (A)	289	338	384	400
(c) Fescue (A)	8	60	114	9
(d) Bermuda (A)	30	28	26	26
(e) Native (A)	562	512	460	565
(h) Protein Supplement (T)				0.6

[1]Feeds utilized by each livestock enterprise are reported in parenthesis and correspond to the letters noted in the pasture and feed section.

production enters the set of ranch plans earlier but does not increase as much as in the base scenario. Stocker enterprises switched from predominantly heifer activities in the base to exclusively steers under this scenario. All stocker average daily gain assumptions were reduced by twenty percent. Base-level heifer gains are approximately 95 percent of steer gains for the same enterprise; therefore, heifers are penalized less by the assumed reduction in productivity. However, this decline in expected rate of gain is enough in absolute terms to eliminate heifers as an economically feasible production alternative. The only exception to this result is the retention of the fall-weaned heifers in the winter roughed enterprise. Although compensatory gains were also reduced in this activity, total gains are sufficient to provide an adequate net return.

Due to the lower marginal value of forage in the production of beef, fall pasture stockers are sold prior to the grazeout period, thus allowing wheat to be harvested as grain. Calves from the spring calving herd are retained in the identical stocker enterprises as resulted with the base solution. However, calves from the fall calving herd are sold at weaning instead of being retained on deferred summer pasture as in the base model. This change is due to the relatively high penalty of the reduced growth rate on deferred pasture stockers. Young animals on late summer pasture will have relatively low average rates of gain without heavy protein supplementation. For the base model average daily gain assumptions were one pound per day. The added reduction in growth assumed for this scenario results in a situation where the cost of holding these calves exceeds projected returns.

Due to the decreased value of forage in the production of beef, grain production has a higher marginal value and thus enters the set of farm plans earlier and at a greater level than occurred with the base. In this scenario, 88 percent of the acreage available for small-grain pasture in the combined solutions is used for grain production with the remaining twelve percent being used for forage. In the base, only 36 percent of the acreage available for small-grain production is used for grain production. Native pasture makes up a greater part of the forage compliment under all farm plans in this scenario. This is due to the lower marginal value of all forage in the production of beef. Due to the lower cost associated with the production of native pasture, the marginal value is still sufficient to cover the cost of production. The relatively high cost of producing improved forages reduces their use in each of the alternate farm plans.

Hay production is also eliminated in this scenario. Again, due to the lower marginal value of forage in the production of beef, the value of feeding hay has declined to the point where the additional revenue generated by feeding hay is insufficient to cover hay production or purchase costs. Also, at the most risk-averse point in this model protein supplement is included in the plan at a minimal level. Protein supplement is fed to the heifers kept on the maintenance diet as a source of nutrition during the winter period.

Native Range Scenario

As pointed out in the description of the study area in Chapter I, eastern Oklahoma has a very diverse terrain. Portions of the study area, particularly the southern portion, have such rugged topography and shallow topsoil that the production of improved forages is not possible on certain ranches. Cattle production is still a major enterprise in these exclusively native range settings. This scenario was developed to analyze risk efficient farm organizations for producers whose forage resources are limited to native pasture and supplemental feed. The model was constrained to allow only the production of native range on the 1,000 acre base. Fixed costs were adjusted to reflect that only native pasture is produced. From the base machinery compliment listed in Table IX, the grain drill and disk were eliminated. In addition, fencing costs were reduced to reflect a larger average pasture size than is assumed with improved grass and small grain pastures. All other assumptions are identical.

The E-A frontier for this scenario is illustrated in Figure 9, and the ranch plans corresponding to the alternate points on the frontier are listed in Table XIX. Expected returns for the LP solution are $31,842 below the base model, while total negative deviations are reduced $28,487. The E-A frontier for this scenario is steeper than the frontier derived with the base model, indicating that the cattle producer in a native range setting has less opportunity to reduce risk without adversely affecting expected income. This result indicates the value of forage diversification in developing risk-reducing strategies. A high degree of the variability in ranch income is derived from deviations in forage production. Thus, the producer who has the ability to diversify his forage plan, particularly among warm and cool season grasses, can greatly enhance his risk-return tradeoff.

The livestock plan is limited to the production of summer stocker heifers. As occurred in previous scenarios, as risk is reduced the number of animals decreases. Also, early- summer intensively stocked heifers are eliminated from the optimum ranch plan. This trend is due to the higher variability associated with an IES enterprise. IES has increased risk due to the heavy numbers employed and thus the greater susceptibility to adverse price movements. Also, due to the heavier stocking rates, adverse weather conditions have a more dramatic effect than when a season-long scheme is used.

Protein supplement is included as an integral part of the feed supply under all risk assumptions. However, in the LP solution, sufficient levels are fed

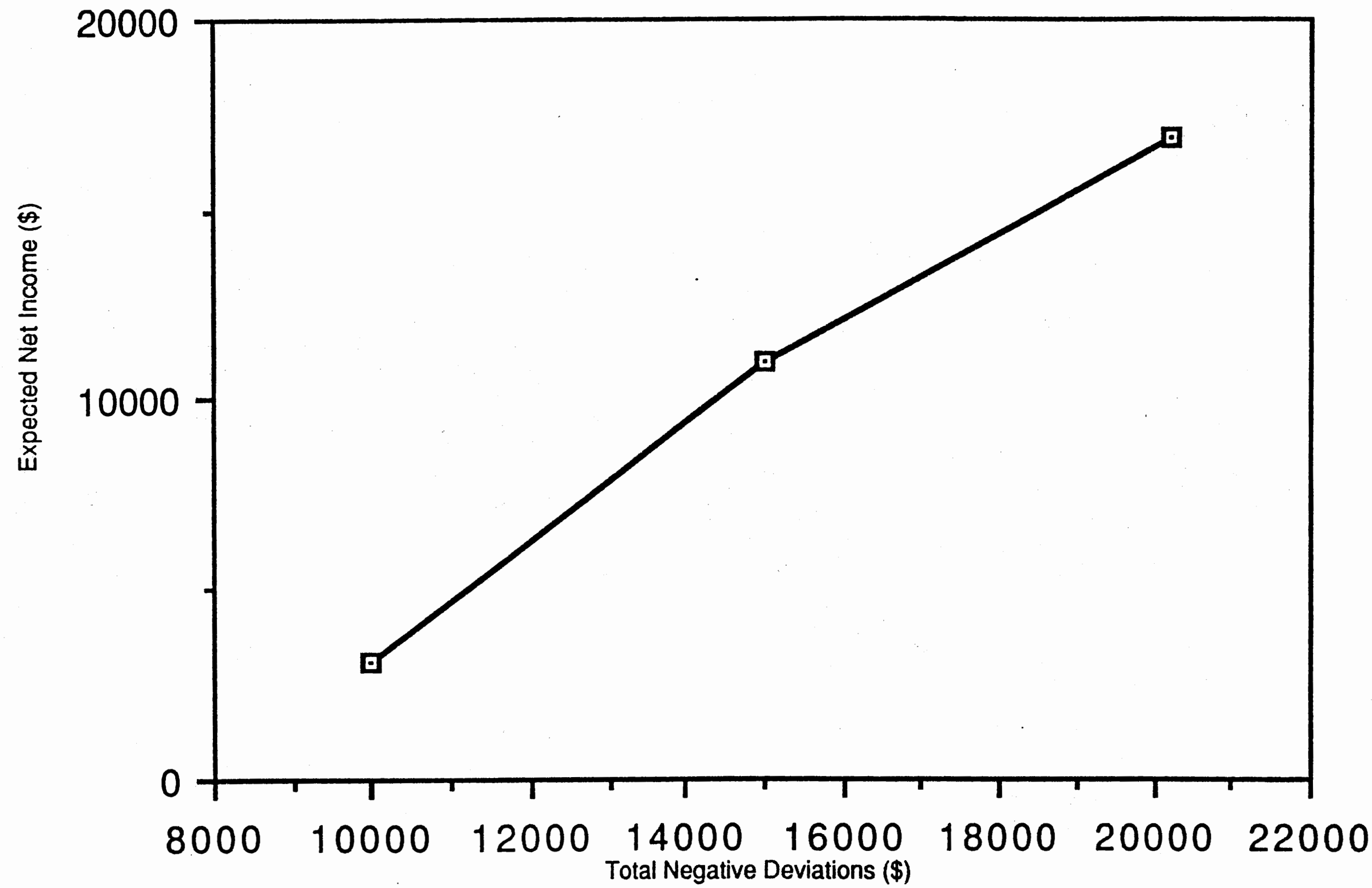

Figure 9. E-A Efficient Farm Organization: Native Range Scenario

TABLE XIX

E-A EFFICIENT FARM ORGANIZATION: NATIVE RANGE SCENARIO

	Farm Plan		
	A	B	C
Total Negative Deviations ($)	20,249	15,000	10,000
Expected Net Returns ($)	16,893	10,975	3,143
Livestock Activities (head)[1]:			
Summer Stocker Heifers IES	13 (d)		
Summer Stocker Heifers SL	982 (d)	932 (d)	836 (d)
Pasture & Feed Activities:			
(e) Native (A)	1,000	1,000	896
(h) Protein Supplement (T)	20	12	11

[1]Feeds utilized by each livestock enterprise are reported in parenthesis and correspond to the letters noted in the pasture and feed section.

to serve as an alternative to low forage production. Thus, as frequently occurs when risk is ignored, the resulting stocking rates are developed to consume all forage produced under favorable forage conditions with little regard for years with below average production. Sufficient supplement is purchased to eliminate feed deficiencies during years of below average forage production. In the two risk averse farm plans, protein supplement is fed only during the latter part of the summer as required to maintain efficient rates of gain when forage quality has declined to the point where rangeland can no longer supply the necessary level of nutrition.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The importance of beef cattle production in Oklahoma is a well documented fact. Oklahoma shares a significant portion of the total beef cattle inventory and production of the United States. In addition, beef cattle constitute the most important single commodity for the Oklahoma agricultural sector, in terms of total cash received by farmers and ranchers and by the high proportion of farms devoted to beef production.

The eastern portion of Oklahoma contributes significantly to the states total beef production, particularly in terms of beef brood cows. Cow-calf operations in the eastern portion of Oklahoma are relatively small size units characterized by the use of more intensive production practices than are employed in other parts of the state. Due to the relatively intense management strategies employed on eastern Oklahoma ranches, information related to alternative beef and forage production techniques. In addition, a more detailed knowledge of the expected income and risk associated with these alternative production practices is needed.

The objective of this study was to develop a model which incorporated risk due to variability in forage yields and cattle prices as a decision constraint, and use the model to identify efficient livestock-forage production systems for commercial cattle producers in eastern Oklahoma characterized by alternative risk preferences. Specifically, the study was conducted to determine the relationships between the expected value and variance of returns derived from alternative production organizations.

Method of Analysis

The method of analysis employed in order to fulfill the study objectives was a modification of the MOTAD (minimization of total absolute deviation) model. The MOTAD framework accomplishes risk measurement in a linear programming model through linear approximation, using absolute deviations as a measure of risk. The method considers expected income (E) and absolute deviation (A) as the crucial parameters in the selection of an efficient farm plan (those having maximum E for a given A). E-A (expected income-absolute deviation) frontiers were developed for several different production scenarios to analyze the effect of various production constraints on income-risk relationships. These multiple solutions gave points of profit maximization for specified levels of risk, subject to the normal technical restrictions of the LP model plus additional linear constraints.

Total acreage in the model was constrained so that the sum of all acres used in the production of the alternate forage sources could not exceed the total acreage available (1,000 acres). Each forage activity was calculated on a per acre basis and no double cropping of the land base was permitted. A separate production-consumption constraint was incorporated for each of the six subperiods included in the model. The constraints were specified to insure that the total consumption of a particular forage by all livestock enterprises did not exceed the total availability of dry matter during the subperiod. Hay production, purchasing and selling activities were also included; thus, the forage supply and demand balance could be altered through a hay feeding activity.

Nutrient supply and demand constraints were developed and incorporated for each of the alternative livestock classes. Energy, protein, and intake constraints were specified for each livestock class to force the model to meet or exceed livestock nutrient requirements without exceeding the intake capacity for the respective livestock class during each subperiod that the animal was consuming forage. If a particular feed was unable to meet the nutrient requirements of a specific livestock class without exceeding the animals intake capacity, the model forces the animal to be supplemented with a higher quality feed. This supplementation could occur through any combination of the available forages or supplements available during the specific subperiod.

Marketing constraints were included to allow the model to sell or retain the various livestock classes at several different points throughout the production period (e.g., weaned calves could be sold at weaning or retained in several alternative stocker enterprises). Alternative sell dates were included for each of the stocker activities to represent the marketing decisions faced by livestock producers.

Forage supply was based on the average forage supply for each individual forage during a six year period. Deviations from the average yield were included in the model to represent the variability in production of each of the alternate forage sources. To value the yield deviations, dry matter deviations were converted to deviations in megacalories of energy supplied during each subperiod. Deviations in forage supplies between years were given monetary value by valuing the megacalories in excess or shortage. Prices paid and received for hay in Oklahoma were used to determine the value of the energy supplied by the alternate forages.

The value of forage deviations was included with net return deviations from variability in the prices of beef, and other selected inputs (e.g., fertilizer, protein supplement, stocker calves). The sum of these positive and negative net return deviations for the six years included in the data set, were then transferred to a risk constraint where positive and negative deviations for each of the six years have an equal probability of occurring and are weighted accordingly. The sum of all deviations weighted by the probability of their occurrence yields the mean absolute deviation from the expected income. This value was then constrained at various levels to derive risk-efficient farm organizations at alternative risk levels.

Information provided by the alternate farm plans includes the: a) forage production system, b) livestock production plan, c) grazing schedule and supplemental feed program, and d) calf marketing strategies. All of this information is relevant and useful to assist producers in the region in better adjusting their resources to maximize their profit potential and expand total output efficiently. Finally, comparison of the results obtained in this study to other research findings will assist in supporting former conclusions or pointing to areas worthy of additional research.

High level management for animal and forage practices were assumed in the data analyzed. Variable and fixed costs (except charges for land and management) were charged to all production activities included in the model. For animal selling activities, an average price for six years (1981-1986) inflated to 1986 were used in the objective function and also in the risk portion of the model. Forage yields consisted of six years of data and were reduced thirty percent for improved forages and sixty-five percent for native range, to allow for trampling, refusal, and sound grazing management practices. An extra ten percent loss in yield was assumed when forage was harvested as hay.

Summary of Results

The model was developed for a representative eastern Oklahoma ranch with a land base of 1,000 acres. The land base was divided among ground with the potential to produce only grass, both native and improved, and ground that had the potential to produce improved forages or small grains. 600 acres were allotted to the former, with the remaining 400 being allotted to the latter. Several different cow-calf and stocker production activities were included in the model to determine the most risk-efficient combination of beef-forage enterprises. In the alternative scenarios to the base, adjustments were made in the production assumptions in order to analyze the effect on risk-return relationships.

Base Scenario: In the base scenario, land was divided into two categories, 400 acres were allotted to either small grain or improved pasture production and the remaining 600 acres were limited to the production of native range or improved pasture. All cow-calf and stocker activities considered in the study were included as potential production practices for this scenario.

The LP solution resulted in expected net returns of $68,555 and total negative deviations of $48,735. The organization of the farm to achieve this risk-return tradeoff is to devote 400 acres, the maximum possible, to rye production and the remaining 600 acres being divided between fescue, native, and bermuda pastures. Approximately 406 tons of bermuda are harvested and fed as hay during the winter months when forage production is low and inconsistent. All forage production is devoted to stocker consumption, with 1484 low-gain heifers being maintained from November 1 through the grazeout period, May 15, and 406 summer stocker heifers being fed from May 1 to October 1.

As risk is reduced, cow-calf production replaces stocker production. Initially, summer stockers are replaced by the fall-calving cow-calf enterprise due to their competing requirement for high quality forage during the first part of summer. Fall stockers are also gradually reduced as risk is constrained and the cow-herd increases. The most dramatic decrease in fall stockers occurs in the most risk averse plan where a spring-calving herd is added to the production plan. In this most risk averse plan, expected farm income is $36,042 with total negative deviations of $10,000. All calves produced in both cow-calf herds are retained in stocker production enterprises. Calves weaned from the fall-calving herd are placed on bermuda pasture from the time of weaning, July 15, until they are sold October 1. Steers weaned from the spring-calving herd are placed in the fall stocker enterprise where they receive a ration consisting of rye, fescue and deferred native pasture until they are sold March 15. Heifers from the spring-calving herd are kept on a maintenance diet through the fall, winter, and spring, and then receive a diet of bermuda and native grass during the summer period. Protein supplement is added during the latter part of the summer when forage quality declines.

Forage trends follow the needs of the different livestock classes for higher quality forage during summer or winter months. Initially, bermuda is a major component of the forage plan due to the requirement for hay. When hay is not produced, bermuda grass acreage declines drastically, then gradually increases to provide forage for the late-season stockers retained from the fall calving herd. The acreage of other grasses remains fairly constant, with minor adjustments following the livestock trends. Small grain production follows a general trend of grain production replacing forage grazeout as risk is reduced. In the most risky farm plan, all potential small grain acreage is devoted to rye, and thus, grazeout production. Gradually, rye is replaced until almost all small grain acreage is devoted to grain production in the most risk averse plan.

Forage Transfer Exclusion Scenario: In this scenario the potential to defer forage produced in one subperiod for consumption in subsequent subperiods was eliminated. This constraint was incorporated to determine the effect of the exclusion of a forage transfer activity on the risk-return relationships. Several studies reviewed for this research did not explicitly include this common producer practice in their models. All other assumptions stated in the base model were kept constant in this scenario.

The exclusion of the forage transfer activity between subperiods resulted in expected net income being decreased $13,473 below base values, while total negative deviations were increased $34,851. A more diverse production plan is used to efficiently utilize the different forages grown during their productive stages. Also, the cow-calf enterprise enters the farm plan later, or after risk has been more tightly constrained, than in the base scenario. Summer stockers are more prevalent in this scenario than in the base. Also, early-summer stockers are included in the riskier plans and then eliminated as risk is reduced. Similar to the base, low-gain grazeout heifers are a major part of the production plan; however, in this case they remain a significant part of the farm plan at all levels of risk.

Native pasture plays a more prevalent role in the forage plan due to its low cost of production and favorable effect on risk. Grain production replaces the grazeout enterprise at approximately the same risk level and in a very similar relative magnitude to that found in the base. Two additional variations between this scenario and the base are also important. First, in order to reduce negative deviations to $10,000, it is necessary to leave 481 acres idle. This result illustrates the lower marginal value of land in the production of beef, as well as the unprofitability of producing hay for sale. A second important difference concerns the supplemental feeding program. As expected the marginal value of supplemental feed has increased due to the inability to defer pasture to periods of low forage production. However, in this scenario, the largest portion of the supplemental feed is purchased as opposed to the base where only ranch produced hay was used. Due to the inability to defer forage for later consumption, the marginal value of bermuda grass increased and thus the marginal value of purchased hay also increased.

Exclusion of Deferred Weaning Scenario: In this scenario the prevalent cow-calf activity in the base solution was eliminated to determine the relative dominance of this particular cow-calf enterprise over other potential cow-calf activities. This was deemed pertinent since fall-calving with deferred weaning is not the most widely practiced cow-calf production practice employed in the study area, even though some producers do follow such a production plan. From a risk-return standpoint, little difference existed between the fall-calving deferred weaning herd and the more typical spring-calving herd. The largest divergence in expected income at identical risk levels was $1,264 and occurred only after total negative deviations had been reduced by over $38,000 to the most risk-averse farm plan. The spring calving herd entered the farm plan at the same point and in almost the identical magnitude as the fall calving herd in the base solution. As risk was reduced the prevalence of the spring-calving enterprise increased only slightly slower than the fall-calving deferred-weaning enterprise in the base. In neither solution did a fall calving with the traditional 210-day weaning scheme enter the production plan. Identical stocker enterprises were included in both scenarios, and the magnitude of their decline as risk was reduced was almost identical in both cases.

Summer forages were slightly more prevalent in this scenario than in the base due to the spring-calving enterprise's requirement for high quality forage during the latter half of the summer. Also, protein supplement use was increased slightly due to the larger number of retained heifers which require protein supplement during the latter part of the summer and during periods of insufficient forage supply in the winter. Hay is also slightly more valuable and is used during periods of insufficient forage for the retained heifers and the cow herd. The small grain forage-grain tradeoff is very similar to the relationship found in the base. Grain production enters the ranch plans sooner in this case than in the base but does not increase quite as rapidly as occurred in the base scenario.

Reduced Production Scenario: In this scenario a lower production function was assumed for cattle growth and reproductive values. Base assumptions were based upon NRC and Oklahoma State University research data and may not be representative of livestock performance realized by several producers in the region. Thus, this scenario was developed to represent production conditions where, due to herd genetics, management skills, or a host of other causes, the producer is operating on a lower response function than is assumed in the base model. To represent this lower level of production, weaning rates and weights were lowered by ten percent and animal average daily gain assumptions were decreased twenty percent. All nutrient requirements were maintained at the level required for higher production.

The decreases in the productivity of the livestock classes resulted in a lower LP solution both in expected farm income and total negative deviations. Expected net income for the LP solution decreased $52,601, while total negative deviations declined $26,123. Thus, the ratio of expected net income to total negative deviations declined from 1.4:1 to .71:1 or by almost 50 percent.

The E-A frontier for this scenario was considerably less steep than in the base, reflecting a greater ability to reduce risk for each dollar of expected income foregone.

The fall-calving deferred-weaning enterprise was a more prevalent part of the alternative ranch plans in this scenario than in the base. This was due to the low level of risk at which the LP solution occurred as actual numbers were not that much different than the base at similar risk levels. Heifers were penalized less on an absolute basis than steers, but the penalties were sufficient to eliminate purchased heifers from the stocker enterprises employed. Stocker enterprises included are quite similar to the base, with the exception of heifers being replaced by steers. Stocking densities in this scenario were considerably less than those derived in the base, reflecting the lower productivity of the livestock enterprises. Weaned calves from the fall-calving cow herd were sold at weaning in lieu of retained ownership. The production penalty on retained late summer stockers was sufficient to render this activity unprofitable. Calves from the spring-calving herd, which entered the production in the most risk-averse plan, were retained as in the base.

Due to the lower productivity of forages in the production of beef, the marginal value of forage production was reduced. This was reflected in a greater portion of the small-grain acreage being devoted to grain production in all ranch plans under this scenario than occurred in the base. Also, this decrease in marginal value of forage production was reflected in a greater quantity of the land base being allotted to native range production, with its lower cost of production, than occurred in the base. Improved pasture production was greatly reduced as marginal returns were no longer sufficient to cover the costs of production. Also, hay was no longer an economical feed source. Protein supplement was still an efficient nutrient source for the winter-roughed heifers in the most risk averse plan.

Native Range Scenario: This scenario was developed to portray the risk-return tradeoffs faced by the eastern Oklahoma producer who, due to soil, topography, or management decisions is constrained to the use of native range exclusively. In this setting the potential to grow improved pastures and small grains were eliminated from the production possibilities. The land base was assumed to consist of 1000 acres of native range. Fixed costs were also reduced in order to reflect the smaller machinery compliment required for a ranch consisting exclusively of range.

By eliminating the use of improved forages from the production possibilities, expected net income was decreased $51,662 while total negative deviations for the LP solution declined $28,486. Thus, the ratio of expected net income to total negative deviation was lower in this scenario than in the base. In addition, the E-A frontier was steeper reflecting a greater penalty to expected income as risk is reduced. This illustrates the fact that the producer relegated to a native range setting has less opportunity to reduce risk due to the fact that a major risk averting method is through the use of a diversified forage system. This ability to reduce risk is also hampered by the fact that since off-season forage cannot be produced, the number of economically feasible livestock enterprises is greatly reduced.

Initially, two stocker enterprises are employed, early- summer and season-long stocker heifers. As risk is reduced, the early-summer stocker enterprise is eliminated and stocking densities are reduced. In order to achieve the most risk-averse farm plan, 104 acres are left idle. Protein supplement is required in order for late summer stocker gains to be maintained. Cows do not enter the production plan under any of the risk levels modeled, reflecting the high penalty associated with deferral of native grass to off-season consumption due to the severe reductions in forage quality.

General Conclusions

The value of the adapted MOTAD model was recognized as an analytical tool to simultaneously evaluate expected levels of net returns and risk under alternative farm organizations. Through the use of the model developed for this study, the traditional linear programming profit maximum farm plan can be derived. In addition, the model provides a wide range of alternative farm plans that, although characterized by lower expected incomes, may be attractive to certain producers due to lower levels of variation around the expected income level.

Results of the analysis indicate that efficient farm plans are quite sensitive to the producers degree of risk aversion. Due to this level of sensitivity to risk reduction strategies, ignoring risk in studies attempting to identify efficient cattle- forage production systems may result in erroneous normative prescriptions. The derived E-A frontiers illustrate some ability for the beef-forage producer to reduce risk without severely reducing his expected level of income. Forage diversification, reduction in pasture stocking densities and substitution towards less volatile livestock enterprises all constitute important risk reduction strategies available to eastern Oklahoma cattle producers.

It is recognized that the specific results derived in this study are specific to eastern Oklahoma due to the site specificity of the data employed. However, the model formulation does provide a means of more accurately representing the relationships between risk and expected returns in beef cattle production. In addition, the general risk reduction strategies derived from the model are applicable to livestock production settings in other regions.

Limitations and Need for Further Research

In the process of conducting this research various difficulties were encountered. These problems provide several opportunities for future research and can be summarized as follows:

a) MOTAD is essentially a static model in that a long-run plan of how the producer should organize his ranch is presented. As such, it lacks a dynamic component allowing for the continuous transition from the present situation to the desired ultimate goal.

b) Availability of forage yield and quality data was incomplete and necessitated estimates in several instances. More complete forage data, on a wider variety of forage types, with alternative fertilization schemes, and with direct forage quality data would aid in more closely representing the actual farm setting.

c) Cattle performance assumptions were based upon NRC and Oklahoma State University research values of potential cattle gains. Actual data relating cattle productivity to alternate levels of nutritional intake in a typical producer setting would solidify the gain assumptions made.

d) In meeting livestock nutrient requirements, the model allocates that combination of feeds which most efficiently meets the nutrient requirements of the respective livestock classes. In certain solutions derived in this study this involved the use of some portion of several different feed sources. While the feasibility of this practice is possible, the practice is probably not possible from a practical standpoint. Lack of exact information regarding livestock nutrient requirements and forage nutrient supplies, as well as the detailed management requirements necessary to allocate the correct proportions of the alternate forages may prevent the use of such complex forage allocations.

e) Production risk is valued at the cost of supplemental feed required to make up for forage deficits. In actual practice, during a low forage production year, it may be more economical to allow livestock to experience reduced gains rather than provide the supplement necessary to sustain constant gains. Conversely, in years of excess feed supply, it may be profitable to increase the level of supplement to experience higher livestock gains. Such decisions are dynamic in nature and thus only estimated by a static model.

f) Brood-cow nutrient requirements were based upon a 1,000 pound cow maintained in a constant body condition. In actual practice, a brood-cows body condition will vary throughout the year depending on the stage of gestation, lactation and general forage conditions. No adjustments were included to represent the effect of a changing body condition on nutrient requirements and intake levels; therefore, brood-cow nutrient requirements may be slightly over/under specified depending upon the particular point in the production period.

g) Subperiods in the model were defined for bi-monthly intervals to incorporate the quality changes that occur throughout the year. As the subperiod length is reduced the size of the model rapidly expands and quickly becomes unwieldy. However, during a sixty day interval fairly dramatic changes can occur in forage quality and thus a certain amount of nutritional misspecification is possible.

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APPENDIXES

APPENDIX A

FORAGE DRY MATTER VALUES

Table XX

ESTIMATED DRY MATTER PRODUCTION FOR ALTERNATIVE FORAGE

	Wheat	Rye	FescueLF[a]	FescueHF[b]	Bermuda	Native
			(Pounds/Acre)			
1981						
Jan-Feb					420	2291
Mar-Apr	4899	2756	3651		4057	
May-Jun					4639	4166
Jul-Aug					7981	937
Sep-Oct					2220	
Nov-Dec	1143	3539	1112	1236		
1982						
Jan-Feb	200	975				
Mar-Apr	4735	2234	4184	4648		
May-Jun					11,286	5671
Jul-Aug					8254	1280
Sep-Oct					580	263
Nov-Dec	748	2664	1101	1169		
1983						
Jan-Feb	123	2670				
Mar-Apr	3826	629	4144	4396		
May-Jun	1643	1491			6813	5366
Jul-Aug					3067	1206
Sep-Oct					1160	6
Nov-Dec	612	676	197	1268		
1984						
Jan-Feb		2000				
Mar-Apr	3605	1673	4505	4769		
May-Jun		1990			9360	2639
Jul-Aug					340	674
Sep-Oct					1580	
Nov-Dec	1022	2444	1164	1371		
1985						
Jan-Feb	260	2477				
Mar-Apr	3039	413	4380	5159	12507	4049
May-Jun					1693	1331
Jul-Aug					2900	263
Sep-Oct						
Nov-Dec		1788	1153	1345		

TABLE XX (CONTINUED)

	Wheat	Rye	FescueLF[a]	FescueHF[b]	Bermuda	Native
			(Pounds/Acre)			
1986						
Jan-Feb		2319				
Mar-Apr	3088	1864	4338	5061		
May-Jun	22	501			9305	5225
Jul-Aug					4235	687
Sep-Oct					2082	
Nov-Dec						

[a]FescueLF-75 pounds of nitrogen applied annually.
[b]FescueHF-150 pounds of nitrogen applied annually.

APPENDIX B

FORAGE BUDGETS

TABLE XXI

FORAGE BUDGETS

Input	Units	Price	Quantity	Cost
WHEAT				
Wheat seed	Bushel	$3.90	1	$3.90
Nitrogen (N)	Lbs.	0.24	220	53.79
Phosphorus (P)	Lbs.	0.27	60	15.96
Potassium (K)	Lbs.	0.13	60	8.00
Spreader Rental	Acre	1.25	2	2.50
Mach fuel, lube, rep.	Acre	9.84	1	9.84
Total Operating Costs				$93.99
RYE				
Rye seed	Bushel	$4.63	2	$9.25
Nitrogen (N)	Lbs.	0.24	220	53.79
Phosphorus (P)	Lbs.	0.27	60	15.96
Potassium (K)	Lbs.	0.13	60	8.00
Spreader Rental	Acre	1.25	2	2.50
Mach fuel, lube, rep.	Acre	9.84	1	9.84
Total Operating Costs				$100.34
FESCUE HEAVY FERTILIZATION				
Estblshmnt Cost (1/10)	Acre	$120.00	0.1	$12.00
Nitrogen (N)	Lbs.	0.24	150	36.00
Phosphorus (P)	Lbs.	0.27	17	4.68
Potassium (K)	Lbs.	0.13	47	6.16
Spreader Rental	Acre	1.25	2	2.50
Mach fuel, lube, rep.	Acre	0.67	1	0.67
Total Operating Costs				$62.01

TABLE XXI (CONTINUED)

Input	Units	Price	Quantity	Cost
FESCUE LIGHT FERTILIZATION				
Estblshmnt Cost (1/10)	Acre	$120.00	0.1	$12.00
Nitrogen (N)	Lbs.	0.24	75	18.00
Phosphorus (P)	Lbs.	0.27	17	4.68
Potassium (K)	Lbs.	0.13	47	6.16
Spreader Rental	Acre	1.25	2	2.50
Mach fuel, lube, rep.	Acre	0.67	1	0.67
Total Operating Costs				$44.01
BERMUDAGRASS				
Estblshmnt Cost (1/10)	Acre	$110.00	0.1	$ 11.00
Nitrogen (N)	Lbs.	0.24	300	73.37
Phosphorus (P)	Lbs.	0.27	41	10.80
Potassium (K)	Lbs.	0.13	62	8.00
Spreader Rental	Acre	1.25	3	3.75
Mach fuel, lube, rep.	Acre	2.91	1	2.91
Total Operating Costs	$109.83			
NATIVE PASTURE				
Weedmaster	Gallon	$15.75	0.08	$1.31
Mach fuel, lube, rep.	Acre	1.17	1	1.17
Total Operating Costs				$2.48

Adapted from Walker, Lusby, and McMurphy.

APPENDIX C

LIVESTOCK BUDGETS

TABLE XXII

LIVESTOCK BUDGETS

Input	Units	Price	Quantity	Cost
FALL PASTURE STEERS				
Salt and Mineral	Lbs.	$0.09	7.5	$0.67
Marketing Charge	Cwt.	1.72	7.2	12.38
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	7.2	2.52
Mach. Fuel, Lube, Rep.	Hd.	6.17	1	6.17
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Steer Calf	Cwt.	76.91	4.5	346.10
Total Operating Costs[1]				$379.77
FALL PASTURE HEIFERS				
Salt and Mineral	Lbs.	$0.09	7.5	$0.67
Marketing Charge	Cwt.	1.72	6.9	11.97
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	6.9	2.44
Mach. Fuel, Lube, Rep.	Hd.	6.17	1	6.17
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Heifer Calf	Cwt.	64.30	4.4	279.71
Total Operating Costs[1]				$312.89
LOW-GAIN FALL PASTURE STEERS				
Salt and Mineral	Lbs.	$ 0.09	7.5	$0.67
Marketing Charge	Cwt.	1.72	6.2	10.72
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	6.2	2.17
Mach. Fuel, Lube, Rep.	Hd.	6.17	1	6.17
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Steer Calf	Cwt.	76.91	4.5	346.10
Total Operating Costs[1]				$377.76

TABLE XXII (CONTINUED)

Input	Units	Price	Quantity	Cost
LOW-GAIN FALL PASTURE HEIFERS				
Salt and Mineral	Lbs.	$ 0.09	7.5	$0.67
Marketing Charge	Cwt.	1.72	6	10.32
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	6	2.10
Mach. Fuel, Lube, Rep.	Hd	6.17	1	6.17
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Heifer Calf	Cwt.	64.30	4.4	279.71
Total Operating Costs[1]				$310.90
GRAZEOUT STEERS				
Salt and Mineral	Lbs.	$0.09	12.3	$1.10
Marketing Charge	Cwt.	1.72	8.4	14.44
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	7.2	2.94
Mach. Fuel, Lube, Rep.	Hd.	9.02	1	9.02
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Steer Calf	Cwt.	76.91	4.5	346.10
Total Operating Costs[1]				$385.53
GRAZEOUT HEIFERS				
Salt and Mineral	Lbs.	$ 0.09	12.3	$1.10
Marketing Charge	Cwt.	1.72	8.1	13.97
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	8.1	2.84
Mach. Fuel, Lube, Rep.	Hd.	6.17	1	6.17
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Heifer Calf	Cwt.	64.30	4.4	279.71
Total Operating Costs[1]				$315.72

TABLE XXII (CONTINUED)

Input	Units	Price	Quantity	Cost
LOW-GAIN GRAZEOUT STEERS				
Salt and Mineral	Lbs.	$ 0.09	12.3	$1.10
Marketing Charge	Cwt.	1.72	7	12.04
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	7	2.45
Mach. Fuel, Lube, Rep.	Hd.	9.02	1	9.02
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Steer Calf	Cwt.	76.91	4.5	346.10
Total Operating Costs[1]				$382.64
LOW-GAIN GRAZEOUT HEIFERS				
Salt and Mineral	Lbs.	$0.09	12.3	$1.10
Marketing Charge	Cwt.	1.72	6.8	11.61
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	6.8	2.38
Mach. Fuel, Lube, Rep	Hd.	6.17	1	6.17
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Heifer Calf	Cwt.	64.30	4.4	279.71
Total Operating Costs[1]	$312.90			
WINTER SUPPLEMENTED STEERS: EARLY SUMMER				
Salt and Mineral	Lbs.	$0.09	14.6	$1.31
Marketing Charge	Cwt.	1.72	7.7	13.35
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	7.7	2.72
Mach. Fuel, Lube, Rep.	Hd.	2.24	1	2.24
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Steer Calf	Cwt.	76.91	4.5	346.10
Total Operating Costs[1]				$377.65

TABLE XXII (CONTINUED)

Input	Units	Price	Quantity	Cost
WINTER SUPPLEMENTED HEIFERS: EARLY SUMMER				
Salt and Mineral	Lbs.	$0.09	14.6	$1.31
Marketing Charge	Cwt.	1.72	7.5	12.97
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd	2.08	1	2.08
Custom Hauling	Cwt.	0.35	7.5	2.64
Mach. Fuel, Lube, Rep.	Hd.	2.24	1	2.24
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Heifer Calf	Cwt.	64.30	4.4	279.71
Total Operating Costs[1]				$310.80
WINTER SUPPLEMENTED STEERS: SEASON LONG				
Salt and Mineral	Lbs.	$ 0.09	19	$1.70
Marketing Charge	Cwt.	1.72	10	15.50
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	10	3.16
Mach. Fuel, Lube, Rep.	Hd.	4.51	1	4.51
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Steer Calf	Cwt.	76.91	4.5	346.10
Total Operating Costs[1]				$382.30
WINTER SUPPLEMENTED HEIFERS: SEASON LONG				
Salt and Mineral	Lbs.	$ 0.09	19	$1.70
Marketing Charge	Cwt	1.72	9	13.69
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	9	2.80
Mach. Fuel, Lube, Rep.	Hd.	4.51	1	4.51
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Heifer Calf	Cwt.	64.30	4.4	279.71
Total Operating Costs[1]	$318.06			

TABLE XXII (CONTINUED)

Input	Units	Price	Quantity	Cost
WINTER ROUGHED STEERS: EARLY SUMMER				
Salt and Mineral	Lbs.	$0.09	13.5	$1.21
Marketing Charge	Cwt.	1.72	6.6	11.37
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	6.6	2.31
Mach. Fuel, Lube, Rep.	Hd.	4.27	1	4.27
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Steer Calf	Cwt.	76.91	4.5	346.10
Total Operating Costs[1]				$377.19
WINTER ROUGHED HEIFERS: EARLY SUMMER				
Salt and Mineral	Lbs.	$0.09	13.5	$1.21
Marketing Charge	Cwt.	1.72	6.4	10.94
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	6.4	2.23
Mach. Fuel, Lube, Rep.	Hd.	4.27	1	4.27
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Heifer Calf	Cwt.	64.30	4.4	279.71
Total Operating Costs[1]				$305.17
WINTER ROUGHED STEERS: SEASON LONG				
Salt and Mineral	Lbs.	$0.09	17.5	$2.06
Marketing Charge	Cwt.	1.72	7.9	13.52
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	7.9	2.75
Mach. Fuel, Lube, Rep.	Hd.	6.54	1	6.54
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Steer Calf	Cwt.	6.91	4.5	346.10
Total Operating Costs[1]				$382.90

TABLE XXII (CONTINUED)

Input	Units	Price	Quantity	Cost
WINTER ROUGHED HEIFERS: SEASON LONG				
Salt and Mineral	Lbs.	$0.09	17.5	$2.06
Marketing Charge	Cwt.	1.72	.6	13.02
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	7.6	2.66
Mach. Fuel, Lube, Rep.	Hd.	6.54	1	6.54
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Heifer Calf	Cwt.	4.30	4.4	279.71
Total Operating Costs[1]				$315.92
SUMMER STOCKER STEERS: EARLY SUMMER				
Salt and Mineral	Lbs.	$0.09	5.2	$0.47
Marketing Charge	Cwt.	1.72	5.7	9.74
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	5.7	1.98
Mach. Fuel, Lube, Rep.	Hd.	4.22	1	4.22
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	.85
Steer Calf	Cwt.	84.91	4	336.84
Total Operating Costs[1]				$365.18
SUMMER STOCKER HEIFERS: EARLY SUMMER				
Salt and Mineral	Lbs.	$0.09	5.2	$0.47
Marketing Charge	Cwt.	1.72	5.4	9.25
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	5.4	1.88
Mach. Fuel, Lube, Rep.	Hd.	4.22	1	4.22
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Heifer Calf	Cwt.	69.06	3.9	267.26
Total Operating Costs[1]				$295.01

TABLE XXII (CONTINUED)

Input	Units	Price	Quantity	Cost
SUMMER STOCKER STEERS: SEASON LONG				
Salt and Mineral	Lbs.	$0.09	6.8	$0.61
Marketing Charge	Cwt.	1.72	6.4	11.03
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	6.4	2.24
Mach. Fuel, Lube, Rep.	Hd.	5.32	1	5.32
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Steer Calf	Cwt.	84.21	4	336.84
Total Operating Costs[1]				$367.97
SUMMER STOCKER HEIFERS: SEASON LONG				
Salt and Mineral	Lbs.	$0.09	6.8	$0.61
Marketing Charge	Cwt.	1.72	6.1	10.52
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	6.1	2.14
Mach. Fuel, Lube, Rep.	Hd.	5.32	1	5.32
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Heifer Calf	Cwt.	69.06	3.9	267.26
Total Operating Costs[1]				$297.78
LOW-GAIN SUMMER STOCKER STEERS: EARLY SUMMER				
Salt and Mineral	Lbs.	$0.09	5.2	$0.47
Marketing Charge	Cwt.	1.72	5	8.65
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.00	1	2.08
Custom Hauling	Cwt.	0.35	5	1.75
Mach. Fuel, Lube, Rep.	Hd.	4.22	1	4.22
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Steer Calf	Cwt.	84.91	4	336.84
Total Operating Costs[1]				$363.86

TABLE XXII (CONTINUED)

Input	Units	Price	Quantity	Cost
LOW-GAIN SUMMER STOCKER HEIFERS: EARLY SUMMER				
Salt and Mineral	Lbs.	$0.09	5.2	$0.47
Marketing Charge	Cwt.	1.72	4.8	8.26
Vet and Med	Hd.	900	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	4.8	1.68
Mach. Fuel, Lube, Rep.	Hd.	4.22	1	4.22
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Heifer Calf	Cwt.	69.06	3.9	267.26
Total Operating Costs[1]				$293.82
LOW-GAIN SUMMER STOCKER STEERS: SEASON LONG				
Salt and Mineral	Lbs.	$0.09	6.8	$0.61
Marketing Charge	Cwt.	1.72	5.5	9.46
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	5.5	1.93
Mach. Fuel, Lube, Rep.	Hd.	5.32	1	5.32
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Steer Calf	Cwt.	84.21	4	336.84
Total Operating Costs[1]				$366.09
LOW-GAIN SUMMER STOCKER HEIFERS: SEASON LONG				
Salt and Mineral	Lbs.	$0.09	6.8	$0.61
Marketing Charge	Cwt.	1.72	5.3	9.13
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	5.3	1.86
Mach. Fuel, Lube, Rep.	Hd.	5.32	1	5.32
Equip. Fuel, Lube, Rep.	Hd.	0.85	1	0.85
Heifer Calf	Cwt.	69.06	3.9	267.26
Total Operating Costs[1]				$296.11

TABLE XXII (CONTINUED)

Input	Units	Price	Quantity	Cost
LATE SUMMER STEERS				
Salt and Mineral	Lbs.	$0.09	1.6	$0.14
Marketing Charge	Cwt.	1.72	5.7	9.80
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	5.7	2.00
Mach. Fuel, Lube, Rep.	Hd.	1.10	1	1.10
Steer Calf	Cwt.	71.50	5	363.94
Total Operating Costs[1]				$388.06
LATE SUMMER HEIFERS				
Salt and Mineral	Lbs.	0.09	1.6	$0.14
Marketing Charge	Cwt.	1.72	5.5	9.46
Vet and Med	Hd.	9.00	1	9.00
Vet-Med-Lvstk Sup	Hd.	2.08	1	2.08
Custom Hauling	Cwt.	0.35	5.5	1.93
Mach. Fuel, Lube, Rep.	Hd.	5.32	1	1.10
Heifer Calf	Cwt.	62.42	4.9	305.23
Total Operating Costs[1]				$328.94

TABLE XXII (CONTINUED)

Input	Units	Price	Quantity	Cost
SPRING-CALVING 210 DAY WEAN				
Salt and Mineral	Lbs.	$0.09	30.0	$2.70
Vet and Med	Hd.	14.65	1.0	14.65
Vet-Med-Lvstk Sup	Hd.	2.78	1.0	2.78
Personal Taxes	Hd.	5.28	1.0	5.28
Equip. Fuel, Lube, Rep.	Hd.	0.85	1.0	1.13
Herd Bulls	Cwt.	100.00	0.12	12.00
Total Operating Costs[1]				$38.54
Fixed Costs	Value	Quantity	Interest	Cst/Cw/Yr
Brood Cow	$ 425.00	1.0	$42.50	$42.50
Beef Heifer	380.00	0.12	38.00	4.56
Bull	1200.00	0.03	120.00	3.60
Total Fixed Costs				$50.66
Production	Units	Price	Quantity	Value
Commercial Cows	Cwt.	$38.60	1.00	$38.60
Aged Bulls	Cwt.	53.90	0.19	10.24
Total Costs				$89.20
Returns Above Fixed & Operating Costs[2]				($40.36)

TABLE XXII (CONTINUED)

Input	Units	Price	Quantity	Cost
FALL CALVING 210 DAY WEAN				
Salt and Mineral	Lbs.	$0.09	30.0	$2.70
Vet and Med	Hd.	14.65	1.0	14.65
Vet-Med-Lvstk Sup	Hd.	2.78	1.0	.78
Personal Taxes	Hd.	5.28	1.0	5.28
Equip. Fuel, Lube, Rep.	Hd.	0.85	1.0	1.13
Herd Bulls	Cwt.	100.00	0.12	12.00
Total Operating Costs[1]				$41.24
Fixed Costs	Value	Quantity	Interest	Cst/Cw/Yr
Brood Cow	$425.00	1.0	$42.50	$42.50
Beef Heifer	380.00	0.12	8.00	4.56
Bull	1200.00	0.03	120.00	3.60
Total Fixed Costs				$50.66
Production	Units	Price	Quantity	Value
Commercial Cows	Cwt.	$43.63	1.00	$43.63
Aged Bulls	Cwt	57.86	0.19	10.99
Total Costs				$91.90
Returns Above Fixed & Operating Costs[2]				($37.28)

TABLE XXII (CONTINUED)

Input	Units	Price	Quantity	Cost
FALL CALVING 285 DAY WEAN				
Salt and Mineral	Lbs.	$0.09	30.0	$2.70
Vet and Med	Hd.	14.65	1.0	14.65
Vet-Med-Lvstk Sup	Hd.	2.78	1.0	2.78
Personal Taxes	Hd.	5.28	1.0	5.28
Equip. Fuel, Lube, Rep.	Hd.	0.85	1.0	1.13
Herd Bulls	Cwt.	00.00	0.12	12.00
Total Operating Costs[1]				$38.54
Fixed Costs	Value	Quantity	Interest	Cst/Cw/Yr
Brood Cow	$425.00	1.0	$42.50	$42.50
Beef Heifer	380.00	0.12	38.00	4.56
Bull	1200.00	0.03	120.00	3.60
Total Fixed Costs				$50.66
Production	Units	Price	Quantity	Value
Commercial Cows	Cwt.	$42.39	1.00	$42.39
Aged Bulls	Cwt.	57.86	0.19	10.99
Total Costs				$89.20
Returns Above Fixed & Operating Costs[2]				($35.82)

1. Total operating costs include costs determined exogenous to the model. Costs such as supplemental feed were derived by the model and thus excluded from this table
2. Returns above fixed and operating costs are negative due to the exclusion of calf production values. These values are dependent on the marketing strategy employed and are determined by the model.

Adapted from Walker, Lusby and McMurphy.

APPENDIX D

LIVESTOCK NUTRITIONAL REQUIREMENTS

TABLE XXIII

LIVESTOCK DAILY NUTRIENT REQUIREMENTS

Livestock Enterprise	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec
	- - -	- - -	- Subperiod -	- - -	- - -	- - -
Fall Pasture Steers						
Mcals ME	20.5	22.3				17.6
Lbs. CP	1.0	1.0				0.9
Fall Pasture Heifers						
Mcals ME	19.9	21.4				17.5
Lbs. CP	1.0	1.0				0.9
Fall Pasture Low-Gain Steers						
Mcals ME	18.2	19.6				15.9
Lbs. CP	0.9	0.9				0.8
Fall Pasture Low-Gain Heifers						
Mcals ME	17.8	19.0				15.8
Lbs. CP	0.9	0.9				0.8
Grazeout Steers						
Mcals ME		23.0	25.1			
Lbs. CP		1.1	1.1			
Grazeout Heifers						
Mcals ME		22.5	24.0			
Lbs. CP		1.0	1.1			

TABLE XXIII (CONTINUED)

Livestock Enterprise	Subperiod Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec
Grazeout Low-Gain Steers						
Mcals ME		20.7	22.1			
Lbs. CP		0.9	1.0			
Grazeout Low-Gain Heifers						
Mcals ME		19.9	21.2			
Lbs. CP		0.9	0.9			
Winter Supplemented Steers ES						
Mcals ME	13.2	14.3	24.2	22.7		12.2
Lbs. CP	0.6	0.7	1.2	1.0		0.6
Winter Supplemented Heifers ES						
Mcals ME	13.4	14.4	23.5	21.8		12.2
Lbs. CP	0.6	0.7	1.2	1.0		0.6
Winter Supplemented Steers SL						
Mcals ME	13.2	14.3	24.2	23.3	25.2	12.2
Lbs. CP	0.6	0.7	1.2	1.0	1.1	0.6
Winter Supplemented Heifers SL						
Mcals ME	13.4	14.4	23.5	22.3	23.8	12.2
Lbs. CP	0.6	0.7	1.2	1.0	1.0	0.6
Winter Roughed Steers ES						
Mcals ME	8.9	8.9	23.2	20.6		8.9
Lbs. CP	0.4	0.4	1.2	1.0		0.4

TABLE XXIII (CONTINUED)

Livestock Enterprise	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec
	- - - - - - -	- - - - - - -	- - - Subperiod	- - - - - - -	- - - - - - -	- - - - - - -
Winter Roughed Heifers ES						
Mcals ME	9.3	9.3	23.3	19.7		9.3
Lbs. CP	0.4	0.4	1.1	0.9		0.4
Winter Roughed Steers SL						
Mcals ME	8.9	8.9	23.2	21.2	23.2	8.9
Lbs. CP	0.4	0.4	1.2	1.0	1.0	0.4
Winter Roughed Heifers SL						
Mcals ME	9.3	9.3	23.3	20.3	22.0	9.3
Lbs. CP	0.4	0.4	1.1	0.9	1.0	0.4
Summer Stocker Steers ES						
Mcals ME			18.5	16.0		
Lbs. CP			1.0	0.8		
Summer Stocker Heifers ES						
Mcals ME			17.9	14.9		
Lbs. CP			0.9	0.7		
Summer Stocked Steers SL						
Mcals ME			18.5	16.1	16.9	
Lbs. CP			1.0	0.7	0.8	
Summer Stocked Heifers SL						
Mcals ME			17.9	15.5	16.3	
Lbs. CP			0.9	0.7	0.7	

TABLE XXIII (CONTINUED)

Livestock Enterprise	Subperiod Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec
Low-Gain Summer Stocked Steers ES						
Mcals ME			16.0	14.3		
Lbs. CP			0.9	0.7		
Low-Gain Summer Stocked Heifers ES						
Mcals ME			15.9	13.6		
Lbs. CP			0.8	0.6		
Low-Gain Summers Stocked Steers SL						
Mcals ME			16.0	14.0	14.7	
Lbs. CP			0.9	0.7	0.7	
Low-Gain Summer Stocked Heifers SL						
Mcals ME			15.9	14.0	14.7	
Lbs. CP			0.9	0.7	0.7	
Late Summer Steers						
Mcals ME				16.1	16.9	
Lbs. CP				0.7	0.8	
Late Summer Heifers						
Mcals ME				15.5	16.3	
Lbs. CP				0.7	0.7	
Fall-Calving 110 Day Wean Herd						
Mcals ME	26.0	30.7	19.7	22.7	23.5	24.4
Lbs. CP	1.2	1.5	0.9	1.0	1.1	1.2

TABLE XXIII (CONTINUED)

Livestock Enterprise	Subperiod Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec
Fall-Calving 285 Day Wean Herd						
Mcals ME	29.1	32.0	34.2	29.2	23.5	24.4
Lbs. CP	1.4	1.5	1.6	1.3	1.1	1.2
Spring-Calving 210 Day Wean Herd						
Mcals ME	22.7	23.5	24.4	29.3	32.2	19.6
Lbs. CP	1.0	1.1	1.2	1.4	1.6	0.9

VITA

Richard Blaine Rawlins

Candidate for the Degree of

Master of Science

Thesis: A RISK-CONSTRAINED ANALYSIS OF ALTERNATIVE BEEF-FORAGE SYSTEMS IN EASTERN OKLAHOMA

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in Ontario, Oregon, November 12, 1961, the son of Blaine and RosaLee Rawlins.

Education: Graduated from Rimrock Jr.-Sr. High School, Bruneau, Idaho in May, 1980; received Bachelor of Science Degree in Agricultural Economics from the University of Missouri at Columbia in May, 1986; completed requirements for the Master of Science Degree at Oklahoma State University in December, 1988.

Professional Experience: Research Assistant, Department of Agricultural Economics, Oklahoma State University, August, 1986 to August, 1988.